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Sources of Weapon System Cost Growth

Analysis of 35 Major Defense Acquisition Programs

Joseph G. Bolten, Robert S. Leonard, Mark V. Arena, Obaid Younossi, Jerry M. Sollinger

RAND PROJECT AIR FORCE

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Preface

This report is one of a series produced within a RAND Project AIR FORCE project, "The Cost of Future Military Aircraft: Historical Cost Estimating Relationships and Cost Reduction Initiatives." The project is intended to improve the tools used to estimate the costs of future weapon systems. It focuses on the effects of recent technical, management, and government policy changes on cost. This report builds on two earlier RAND studies, *Historical Cost Growth of Completed Weapon System Programs*, by Mark V. Arena, Robert S. Leonard, Sheila E. Murray, and Obaid Younossi, TR-343-AF, 2006, and *Is Weapon System Cost Growth Increasing? A Quantitative Assessment of Completed and Ongoing Programs*, by Obaid Younossi, Mark V. Arena, Robert S. Leonard, Charles Robert Roll, Jr., Arvind Jain, and Jerry M. Sollinger, MG-588-AF, 2007. Arena et al. (2006) quantifies the magnitude of historical cost growth of weapon systems, and Younossi et al. (2007) examines both completed and ongoing programs to determine whether a trend has developed since the 1970s. The present study examines 35 weapon-system acquisition programs to determine the sources of cost growth. It should interest those involved with the acquisition of systems for the Department of Defense and others concerned with cost estimation.

The research reported here was sponsored by the Principal Deputy, Office of the Assistant Secretary of the Air Force (Acquisition), Lt Gen Donald J. Hoffman, SAF/AQ, and Blaise Durante, SAF/AQX, and was conducted within the Resource Management Program of RAND Proj-

ect AIR FORCE. The project's technical monitor is Jay Jordan, Technical Director of the Air Force Cost Analysis Agency (AFCAA).

Other RAND Project AIR FORCE reports that address military cost-estimating issues include the following:

- *An Overview of Acquisition Reform Cost Savings Estimates*, by Mark Lorell and John C. Graser, MR-1329-AF, uses relevant literature and interviews to determine whether estimates of the efficacy of acquisition reform measures are robust enough to be of predictive value.
- *Military Airframe Acquisition Costs: The Effects of Lean Manufacturing*, by Cynthia R. Cook and John C. Graser, MR-1325-AF, examines the package of new tools and techniques known as "lean production" to determine whether it would enable aircraft manufacturers to produce new weapon systems at costs below those predicted by historical cost-estimating models.
- *Military Airframe Costs: The Effects of Advanced Materials and Manufacturing Processes*, by Obaid Younossi, Michael Kennedy, and John C. Graser, MR-1370-AF, examines cost-estimating methodologies and focuses on military airframe materials and manufacturing processes. This report provides cost estimators with factors useful for adjusting and creating estimates based on parametric cost-estimating methods.
- *Military Jet Engine Acquisition: Technology Basics and Cost-Estimating Methodology*, by Obaid Younossi, Mark V. Arena, Richard M. Moore, Mark Lorell, Joanna Mason, and John C. Graser, MR-1596-AF, presents a new methodology for estimating military jet-engine costs; discusses the technical parameters that drive the engine development schedule, development cost, and production costs; and presents a quantitative analysis of historical data on engine development schedule and cost.
- *Test and Evaluation Trends and Costs for Aircraft and Guided Weapons*, by Bernard Fox, Michael Boito, John C. Graser, and Obaid Younossi, MG-109-AF, examines the effects of changes in the test and evaluation (T&E) process used to evaluate military aircraft and air-launched guided weapons during their develop-

ment programs. It also provides relationships for developing estimates of T&E costs for future programs.

- *Software Cost Estimation and Sizing Methods: Issues and Guidelines*, by Shari Lawrence Pfleeger, Felicia Wu, and Rosalind Lewis, MG-269-AF, recommends an approach to improve the utility of software cost estimates by exposing uncertainty and reducing risks associated with developing the estimates.

- *Lessons Learned from the F/A-22 and F/A-18E/F Development Programs*, by Obaid Younossi, David Stem, Mark Lorell, and Frances Lussier, MG-276-AF, evaluates historical cost, schedule, and technical information from the development of the F/A-22 and F/A-18E/F programs to derive lessons for the Air Force and other services on improving future systems acquisition.

- *Price Based Acquisition: Issues and Challenges for Defense Department Procurement of Weapon Systems*, by Mark Lorell, John C. Graser, and Cynthia R. Cook, MG-337-AF, documents for the acquisition, planning, and cost-estimating communities cost savings and cost avoidance in government and contractor activities achieved by using price-based acquisition (PBA) strategies; it also generates recommendations for approaches to more accurately assess the potential cost savings and cost avoidance that can be expected from the wider use of PBA.

- *Impossible Certainty: Cost Risk Analysis for Air Force Systems*, by Mark V. Arena, Obaid Younossi, Lionel Galway, Bernie Fox, John C. Graser, Jerry Sollinger, Felicia Wu, and Carolyn Wong, MG-415-AF, describes various methods for estimating cost risk and recommends attributes of a cost-risk estimation policy for the Air Force.

- *Systems Engineering and Program Management: Trends and Costs for Aircraft and Guided Weapons Programs*, by David E. Stem, Michael Boito, and Obaid Younossi, MG-413-AF, evaluates the historical trends and develops a cost-estimating method for systems engineering and program management (SE/PM), one of the more costly "below-the-line" items for military aircraft and guided weapon systems.

- *Evolutionary Acquisition: Implementation Challenges for Defense Space Programs*, by Mark Lorell, Julia Lowell, and Obaid Younossi, MG-431-AF, provides information to aid the Air Force acquisition community in formulating policies that anticipate and respond to the prospect of more widespread use of evolutionary acquisition strategies relying on a spiral development process, as recently mandated by the Office of the Secretary of Defense (OSD).
- *Historical Cost Growth of Completed Weapon System Programs*, by Mark V. Arena, Robert S. Leonard, Sheila E. Murray, and Obaid Younossi, TR-343-AF, includes a literature review of cost-growth studies and an extensive analysis of the historical cost growth of completed acquisition programs.
- *Is Weapon System Cost Growth Increasing? A Quantitative Assessment of Completed and Ongoing Programs*, by Obaid Younossi, Mark V. Arena, Robert S. Leonard, Charles Robert Roll, Jr., Arvind Jain, and Jerry M. Sollinger, MG-588-AF, analyzes completed and ongoing weapon-system programs' development cost growth, determines the magnitude of cost growth, and shows the cost-growth trend over the past three decades.

RAND Project AIR FORCE

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Contents

Figures

Tables

Summary

Background and Purpose

Previous RAND Project AIR FORCE work has concluded that the Department of Defense (DoD) and the military departments historically have underestimated the cost of new weapon systems. Analysis of the data in Selected Acquisition Reports (SARs)[1] for a sample of 68 completed programs showed that the average total cost growth[2] (after adjusting for procurement-quantity changes) was 46 percent over the baseline estimate made at Milestone B (MS B) and 16 percent over the baseline estimate made at MS C. The cost growth typically continued for about 75 percent of the time between the initiation of major development and the expending of 90 percent of program funding. Most of the cost growth occurred early in the acquisition phase, and the magnitude of development cost growth at completion for programs initiated in the 1970s, 1980s, and 1990s remained relatively steady (Arena et al., 2006).

Although quantifying cost growth is important, the larger issue is why cost growth occurs. To answer that question, this analysis examines 35 mature, but not necessarily complete, major defense acquisition programs (MDAPs) from the database of SARs that document

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[1] SARs are documents prepared by DoD for the U.S. Congress. They cover all major defense acquisition programs. They are submitted at least annually and are required by Public Law 10 USC 2432. For a more detailed discussion of SARs, see Arena et al., 2006, and Drezner et al., 1993.

[2] The average cost growth includes both cost overrun and cost underrun.

the development and procurement of a variety of systems, including aircraft, missiles, electronics systems, launch vehicles, munitions, vehicles, and satellites. The programs were similar in type and complexity to those conducted by the Air Force. We analyzed a relatively small number of programs because of the labor-intensive nature of the work. We first examined the programs as a complete set and then analyzed Air Force and non–Air Force programs separately to determine whether the causes of cost growth in the two groups differed.

Categorizing Cost Growth

The SARs establish a baseline cost estimate at the time of a program's MS B. Changes to that estimate (or "variances") are made and documented as time passes to explain increases or decreases in current and future budgets. In SARs, variances are assigned to the following categories: quantity, schedule, engineering, estimating, economic, other, and support. We defined different variance categories oriented toward the causes of cost growth and then reclassified the variance data from the SARs into our causally oriented structure. Because we wanted to allocate all variance data provided in each SAR, we did not normalize our results for changes in quantity. This approach had the added benefit of illuminating the relative effect of all cost-estimate changes in creating "realized" cost growth, which is the growth that must ultimately be managed within the budgeting process.

Several sets of causally oriented variance categories were explored during the study, each of which presented unique problems (e.g., overlap between categories, ambiguity in assigning growth, infrequently used categories). The final set meets our criteria (e.g., the categories were useful in explaining the causes of growth while being easily differentiated) better than the previous sets, but it may be improved through further revision in the future. This final set allocates cost variance into four major categories: (1) errors in estimation and planning, (2) decisions by the government, (3) financial matters, and (4) miscellaneous sources. As shown in Table S.1, the categories contain several subcategories.

Table S.1
RAND Cost-Variance Categories

Errors in estimation and planning	
Cost estimates	Program rebudgeting caused by an inappropriate initial estimate of costs
Schedule estimates	Program rebudgeting and rescheduling caused by an inappropriate schedule plan
Technical issues	Program replanning and rebudgeting resulting from significant technology development or implementation problems
Decisions by the government	
Requirements	Increase or decrease in program requirements, either with or without additional funding
Affordability	Decision by OSD, Congress, or the service to change the program because of cost issues (reprogramming decisions)
Quantity	Increase or decrease in the quantity of systems built
Schedule	Decision by OSD, Congress, or the service to change the program schedule (extend, contract, or restructure)
Inter- or intraprogram transfers	Color-of-money transfers within a program (between development and procurement or operations and maintenance (O&M)) or between programs
Financial matters	
Exchange rate	Program cost changes associated with differences between predicted and actual exchange rates
Inflation	Program cost changes associated with differences between predicted and actual inflation
Miscellaneous sources	
Error corrections	Variances from errors in the SARs
Unidentified	Unexplained variances
External events	External events affecting program cost, schedule, or technology

Errors made by the government, program contractor, or subcontractors include inaccurate estimation of costs or the inability to conform to initial or revised program schedules. This category also includes problems stemming from unanticipated technical difficulties encountered during acquisition.

Decisions made by DoD include requirements changes (usually associated with added performance and functionality), externally imposed funding changes (not driven by work-scope changes) that are typically precipitated by the need to free up funding for other priori-

ties, changes in the quantity of systems to be acquired, program schedule changes that are not associated with program execution difficulties, and decisions involving intraprogram (between appropriation categories) or interprogram transfers of funds and work scope.

Financial issues include unanticipated inflation levels and changes in exchange rates, which are relevant in programs in which a portion of the system is built by a foreign contractor or in a foreign country.

Miscellaneous sources are items not directly associated with errors in the program or decisions by the government. They include reporting errors, unidentified variances whose origins are simply not described well enough to allocate to any other category, and external events that affect the program but are not a result of errors or decisions directly associated with it.

Results of the Analysis

Overall Cost Growth

Table S.2 shows average development, procurement, and total (development plus procurement) cost growth for the 35 mature programs we examined. The values shown include the effects of changes in quantity. In most cost-growth studies, these effects are removed from the results by normalizing the figures to reflect their expected value if no quantity changes had occurred. Because we have included quantity variances, the results of this study are not directly comparable to those of most prior studies.

Total (development plus procurement) cost growth is dominated by decisions, which account for more than two-thirds of the growth. Most decision-related cost growth involves quantity changes (22 percent), requirements growth (13 percent), and schedule changes (9 percent). Cost estimation (10 percent) is the only large contributor in the errors category. Growth due to financial and miscellaneous causes is less than 4 percent of the overall growth.

Table S.2
Cost Growth, by RAND Category (mean for 35 mature programs)

Category	Development Cost Growth (%)	Procurement Cost Growth (%)	Total Cost Growth (%)
Errors	19.6	14.7	14.6
Cost estimate	18.0	8.4	10.1
Schedule estimate	1.0	0.9	0.9
Technical issues	0.6	5.4	3.5
Decisions	30.7	57.4	41.6
Requirements	17.5	9.5	12.9
Affordability	−1.9	−0.5	−1.3
Quantity	4.3	40.8	21.9
Schedule	6.0	10.0	8.9
Inter- or intraprogram transfers	4.8	−2.4	−0.7
Financial	1.0	1.8	1.4
Exchange rate	0.1	0.1	0.1
Inflation	0.9	1.7	1.3
Miscellaneous	5.2	1.4	2.4
Error correction	−0.5	−0.3	−0.4
Unidentified	−0.3	−0.3	−0.4
External events	6.0	2.1	3.1
Total	56.5	75.4	60.0

The dominant influence of decisions is somewhat unexpected, because previous studies have reported nearly the reverse. A clear contributor is our inclusion of quantity changes, which are responsible for more than one-third of total cost growth and more than half of the total for the decisions category. Also somewhat unexpected is the small contribution of technical issues to average cost growth. Such issues contributed to cost growth in only a few programs.

Errors due to cost estimating account for nearly one-third of the overall development cost growth, and changes in requirements account for almost as much. However, growth due to decisions still dominates development cost growth. More than half of the average procurement cost growth is due to quantity changes. The other two major factors are schedule and requirements changes.

Cost Growth in Air Force Programs

In addition to estimating total cost growth, we examined cost-growth sources separately for the 16 programs that were managed by the Air Force. While the averages of total cost growth for the Air Force programs were somewhat higher than those for the other programs, the differences were not statistically meaningful (see pp. 35–38). The lack of statistical significance results in part from the relatively high values of standard deviation found in both portions of the sample. It does not appear that the Air Force programs perform better or worse than the overall, multiservice average. This result is consistent with results of prior RAND studies, which found no statistically meaningful differences among the military services.

Cost Growth by Program Type

We examined three program-type subsets from the full sample of programs: aircraft and helicopters, missiles, and electronics. Total cost growth for aircraft and helicopters averaged 74 percent; that for missiles averaged 44 percent; and that for electronics averaged 28 percent (see pp. 38–43). Decisions accounted for the majority of cost growth in aircraft and helicopters and missiles, and for virtually all of the cost growth in electronics. Cost estimating was the single largest cost-growth contributor in aircraft and helicopters and missile programs at 27 percent and 15 percent, respectively. Quantity, at 18 percent, was the single largest contributor to cost growth in electronics programs.

By and large, we did not see any statistically significant differences for development cost growth, with the exception that affordability changes tend to be positive for electronics programs (possibly indicating unfunded requirements) and negative in the other programs. Other observed differences in development cost growth were minor, with the exception of greater cost-estimating errors in aircraft and helicopters.

There were some important and statistically meaningful differences in procurement cost growth. Aircraft programs had larger procurement cost growth due to errors in cost estimating and technology issues. The growth due to errors was statistically significant; that due to technology issues was not. Electronics programs had statistically significant lower procurement cost growth due to errors.

Opportunities to Reduce Cost Growth in Weapon-System Programs

Our results show that decisions involving changes in requirements, quantities, and production schedules dominate cost growth. Therefore, program managers, service leadership, and Congress should look for ways to reduce changes in these areas. However, we understand that a careful balance must be struck between containing growth and providing the right capabilities to the warfighter.

Improving the quality of cost estimates, particularly in system development and in aircraft and helicopter procurement costs, would yield the greatest reduction in cost growth. While correction of cost-estimating errors will not directly reduce overall system costs, it will better align expectations with reality and may indirectly provide modest overall cost reductions through reduction in the "churn" of program plans and activities resulting from the common mismatch between them.

Ways to Improve SAR Data

Our attribution of cost variances in the SARs to underlying causes was challenged by inconsistent quality and nonspecific attribution in SAR cost-variance descriptions. More-stringent specifications and consistent application of variance descriptions could greatly enhance the usefulness of the SARs to their customers. In particular, each variance value should be restricted to a single source. Current practice on many programs is to string together two to five apparently unrelated causes and associate a single cost-variance value to the aggregate. This practice makes the variance results essentially meaningless. In addition, we recommend that variances with values over a specified threshold (e.g., $10 million in fiscal year (FY) 2005 dollars) should require a more detailed narrative that describes the events and activities that led to the ultimate recognition of the cause of the variance. Finally, we recommend that OSD consider changing the variance categories in SARs to provide information that is more causally oriented.

Acknowledgments

Abbreviations

AFATDS	Advanced Field Artillery Tactical Data System
AFCAA	Air Force Cost Analysis Agency
AMRAAM	Advanced Medium-Range Air-to-Air Missile
ATACMS	Army Tactical Missile System
AWACS RSIP	Airborne Warning and Control System Radar System Improvement Program
B-1B	long-range multirole strategic bomber
B-1B CMUP Computer	B-1B Conventional Munitions Upgrade Program—Computer
B-1B CMUP JDAM	B-1B Conventional Munitions Upgrade Program—Joint Direct Attack Munition
BFVSA3	Bradley Fighting Vehicle System—A3 Upgrade
C-17	military transport aircraft
CARS	Consolidated Acquisition Reporting System
CBU-97B	sensor-fused weapon
CGF	cost growth factor
DoD	Department of Defense
E-6A	airborne command, control, and communications aircraft

ELEC	electronics-system type
F-22	advanced fighter aircraft
F/A-18E/F	fighter/attack aircraft
FSD	full-scale development
FY	fiscal year
FYDP	Future Years Defense Program
GBS	Global Broadcast System
ICA	independent cost analysis
JAVELIN	antiarmor weapon system
JDAM	Joint Direct Attack Munition
JPATS	Joint Primary Aircraft Training System
JSOW	Joint Standoff Weapon
JSTARS	Joint Surveillance Target Attack Radar System (airborne surveillance aircraft)
JSTARS CGS	JSTARS Common Ground Station
Longbow Apache AF	attack helicopter—airframe upgrade portion
Longbow Apache FCR	attack helicopter—fire-control radar upgrade portion
Longbow Hellfire	short-range radar-guided missile
LS	launch-system type
MCS	maneuver control system
MDAP	major defense acquisition program
MIDS LVT	Multifunctional Information Distribution System—low-volume terminal
MM III GRP	Minuteman III Guidance Replacement Program

MM III PRP	Minuteman III Propulsion Replacement Program
MS B	Milestone B or II
MS C	Milestone C or III
OH-58D	combat-support helicopter upgrade
O&M	operations and maintenance
OSD	Office of the Secretary of Defense
P3I	preplanned product improvement
Patriot PAC3	Patriot advanced capability 3 missile
PBA	price-based acquisition
PPBS	planning, programming, and budgeting system
SAR	Selected Acquisition Report
SE/PM	systems engineering and program management
SMART-T	Secure Mobile Anti-Jam Reliable Tactical Terminal
SRMU	solid rocket motor upgrade
Stryker	infantry carrier vehicle
T&E	test and evaluation
T45TS	advanced jet trainer aircraft
T-II MSL	submarine-launched ballistic missile
Titan IV	heavy-lift space launch system
WGS	Wideband Gapfiller Satellite

CHAPTER ONE

Introduction

Background

Weapon-system cost growth has been a subject of interest in the Department of Defense (DoD) for many years—early RAND studies of weapon-system cost growth date back to the 1950s (Marshall and Meckling, 1959). McNicol (2004), Wandland and Wickman (1993), Tyson, Nelson, and Utech (1992), Shaw (1982), Tyson et al. (1989), Asher and Maggelet (1984), and Drezner et al. (1993) studied cost growth in weapon systems of all types, using data from Selected Acquisition Reports (SARs) and other sources, and reported mixed results, using different measures for varying numbers of weapon systems.

The findings of these studies, described and summarized in Arena et al. (2006), indicate that DoD and the military departments have, by and large, underestimated the cost of buying new weapon systems. Along with a systematic bias toward underestimating costs, there has been substantial uncertainty in estimating the final cost of any particular weapon system. Analysis of SAR data in 68 programs showed that the average total cost growth (adjusted for quantity changes) for a *completed* program was 46 percent over the baseline estimate established at Milestone B (MS B), and 16 percent over the baseline estimate established at MS C. Cost growth continued until about three-quarters of the way through system acquisition. Younossi et al. (2006) examined the development cost growth of the same 68 completed programs plus 33 ongoing weapon-system programs and concluded that most of the development cost growth occurs early in the acquisition process and that the average magnitude of development cost growth at program

completion throughout the 1970s, 1980s, and 1990s remained relatively constant.

Figure 1.1 shows the distribution of cost growth of 46 completed programs.[1] These programs were similar to types procured by the Air Force (e.g., aircraft, missiles, electronics upgrades) and were essentially finished, i.e., more than 90 percent of the production was complete.[2]

The cost growth factor (CGF), the metric used in Figure 1.1, is the ratio of the final cost to that estimated at MS B.[3] A CGF of less than 1.0 indicates that the estimate was higher than the final cost—an underrun. When the CGF exceeds 1.0, the final costs were higher than the estimate—an overrun.

Objective of This Study

Many prior cost-growth studies have attempted to analyze the causes of growth, but they have primarily used an associative characteristic/statistical approach, rather than seeking root causes. The one exception is McNicol (2004), which, like this study, attempted specifically to identify the underlying or root causes of cost growth. We examined 35 mature acquisition programs involving weapon systems similar to those the Air Force procures (i.e., we excluded ships and submarines), a sample large enough to represent all applicable weapon systems yet small enough to accomplish the work with the resources available.

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[1] Cost growth could be measured from MS B for only 46 of the 68 programs. It was measurable from MS C for all 68.

[2] The SAR data were adjusted to account for inflation and changes in the number of systems purchased in the procurement phase. The data used in the present study (for a 35-program dataset) were likewise modified to account for inflation but were not modified for changes in the number of systems purchased. The magnitude of the cost growth for the smaller program set is different, but the shape of the distribution is similar to that shown in Figure 1.1.

[3] We use the current DoD 5000 instruction Milestone A, B, and C designations. These correspond to the older programs' Milestone I, II, and III. For a full discussion and definition of these milestones, see DoD Instruction 5000 or Arena et al., 2006.

Figure 1.1
Distribution of Total Cost Growth from MS B, Adjusted for Procurement Quantity Changes, in 46 Completed Programs
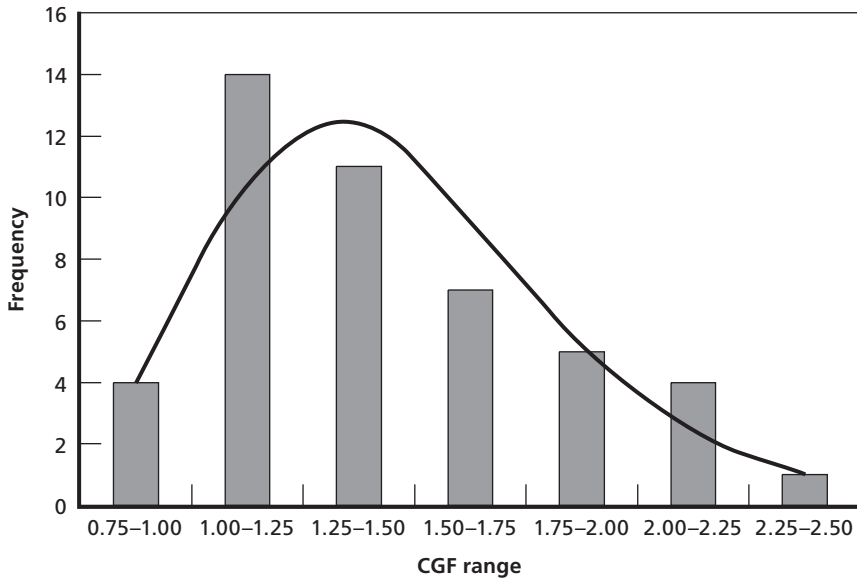
SOURCE: Arena et al., 2006.
RAND *MG670-1.1*

This work included categorization of some 5,000 to 10,000 cost variances reported in the SARs of the programs.[4]

The cost growth we measured includes the effects of changes in quantity. In most cost-growth studies, including most of those cited above, these effects are removed by normalizing the figures to reflect their expected value if no quantity changes had occurred. Our approach is different and was driven by the desire to allocate all variance data provided in each SAR. This approach has the added benefit of illuminating the relative effect of these changes in creating "realized" cost growth, the growth that must ultimately be managed within the budgeting process. Because we do not normalize for quantity changes, our

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[4] Each of the 35 programs has from about eight to 16 SARs, and each SAR contains roughly 10 to 30 variances.

results are not directly comparable to those of most prior cost-growth studies.

Organization of This Report

Chapter Two describes the methodology of the study, Chapter Three presents the results of our analysis, and Chapter Four provides some observations. The report also has four appendices. Appendix A shows the cost growth of all the programs studied, Appendix B summarizes the cost growth through weighted averages, Appendix C explores "trigger events" that cause cost growth, and Appendix D reproduces the current Office of the Secretary of Defense (OSD) guidance for allocating cost variances to the SAR cost-variance categories.

Study Approach

Selection of Programs for Analysis

We selected our sample of 35 acquisition programs from a list of 125 SAR reporting programs that were either completed or currently under way. We used the following selection criteria:

1. At least 35 percent of the planned procurement was funded through fiscal year (FY) 2004.
2. The MS B (full-scale development decision) occurred after 1980.
3. At MS B, the program had a solid baseline estimate for costs and procurement quantity.
4. The program was not canceled or truncated after early production.
5. The program was similar in technical complexity to those undertaken by the Air Force (i.e., ships and submarines were excluded).

The first criterion ensured that the programs were reasonably mature. We did not want to include programs that were likely to experience large changes in cost growth during the remainder of their acquisition. The second criterion ensured that only the most relevant programs were selected, i.e., those that are most representative of modern acquisitions that are systems-integration- and software-intensive. The third simply assured that we had a solid baseline from which program variances were tracked. The fourth ensured that the programs in the

set were representative of those in the future that would be continued through at least some full rate-production. The fifth was intended to maximize the relevance of this work to the Air Force. These criteria are different from those of earlier studies, so our program sample is different as well. We believe that the programs that met these criteria were best suited to determining the underlying causes of cost growth for the Air Force.

Sixteen of the 35 programs that met our criteria are managed by the Air Force, 13 by the Army, and six by the Navy. Six have substantial participation by more than one service (as indicated in Tables 2.1 through 2.4). To categorize these programs by service, the "lead," or managing, service for each is used. The selected programs can be classified by system type, as follows:

1. Aircraft and helicopters (10 programs)
2. Electronics systems (13 programs)
3. Ground vehicles (two programs)
4. Launch vehicles (two programs)
5. Missiles (six programs)
6. Munitions (one program)
7. Satellites (one program).

The programs are shown in Tables 2.1 through 2.4.

The primary factor for determining program type was content value—where the largest fraction of the funding was spent. As a result, some programs are not categorized as one might expect. For example, many think of the Global Broadcast System as a space system, but fewer than a dozen of the system's more than 1,000 information-transmission suites are (or will be) spaceborne. All the rest are located on airborne, land-based, and sea-based platforms. Both joint stand-off weapons (JSOWs) and joint direct attack munitions (JDAMs) are commonly thought of as munitions, and both are in their final forms. However, the acquisition programs for both involve guidance kits affixed to existing munitions; thus the programs (not their products) are truly electronics-systems programs.

Table 2.1
Aircraft and Helicopter Programs (10 programs)

Program Name	Short Form	Service
B-1B Bomber	B-1B	Air Force
C-17A Transport	C-17	Air Force
E-6A TACAMO	E-6A	Navy
F/A-18E/F Fighter/Attack	F/A-18E/F	Navy
F-22 Advanced Tactical Fighter	F-22	Air Force
Joint Primary Aircraft Training System	JPATS	Air Force/ Navy
Joint Surveillance Target Attack Radar System (airborne segment)	JSTARS	Air Force
Longbow Apache Airframe Modifications	Longbow Apache AF	Army
Army Helicopter Improvement Program	OH-58D	Army
Undergraduate Jet Flight Training System	T45TS	Navy

Table 2.2
Electronics-Systems Programs (13 programs)

Program Name	Short Form	Service
Advanced Field Artillery Tactical Data System	AFATDS	Army
Airborne Warning and Control System Radar System Improvement Program	AWACS RSIP	Air Force
B-1B Conventional Mission Upgrade Program—Computer	B-1B CMUP Computer	Air Force
B-1B Conventional Mission Upgrade Program—Joint Direct Attack Munition	B-1B CMUP JDAM	Air Force
Global Broadcast System	GBS	Air Force/ Army/ Navy
Joint Direct Attack Munition	JDAM	Air Force/ Navy
Joint Standoff Weapon System—Baseline & BLU-108	JSOW	Navy/Air Force
JSTARS—Ground Station Module & Common Ground Station	JSTARS CGS	Army
Longbow Apache Fire Control Radar	Longbow Apache FCR	Army
Maneuver Control System	MCS	Army
Multifunctional Information Distribution System—Low-Volume Terminal	MIDS LVT	Navy/ Army/ Air Force
Minuteman III Guidance Replacement Program	MM GRP	Air Force
Secure Mobile Antijam Reliable Tactical Terminal	SMART-T	Army

Table 2.3
Missile Programs (6 programs)

Program Name	Short Form	Service
Advanced Medium Range Air-to-Air Missile	AMRAAM	Air Force/ Navy
Advanced Anti-Tank Weapon System	Javelin	Army
Longbow Hellfire Missile	Longbow Hellfire	Army
Army Tactical Missile System	ATACMS	Army
Patriot Advanced Capability Missile	Patriot PAC3	Army
Trident II Missile	Trident II Missile	Navy

Table 2.4
Other Programs (6 programs)

Program Name	Short Form	Program Type	Service
Minuteman III Propulsion Replacement Program	MM PRP	Launch vehicle	Air Force
Titan IV Complementary Expendable Launch Vehicle	Titan IV	Launch vehicle	Air Force
Cluster Bomb Unit—97B Sensor Fused Weapon	CBU 97B	Munitions	Air Force
Wideband Gapfiller Satellites	WGS	Satellite	Air Force
Bradley Fighting Vehicle System—A3 Upgrade	BFVSA3	Vehicle	Army
Interim Armored-Vehicle Program	Stryker	Vehicle	Army

Selected Acquisition Reports

The cost information for the programs we examined came directly from each program's time-series collection of SARs. The cost-variance data were taken from each SAR's cost-variance section. The SARs provide a narrative update of each program's history and current status and report selected cost, schedule, budget, annual-funding, expenditures, contract, delivery, and performance data. In joint programs (where more than one service is involved), SARs report annual funding by service and a subset of schedule data by participating service or DoD agency. With the exception of quantity variances, they generally do not report cost-variance data by service. All programs subject to SAR reporting provide an annual SAR dated December 31.

Additional interim reports are required if cost or schedule breaches (increases or slips) in excess of specific percentages or durations occur or if a major milestone is achieved. Each service submits its annual SARs within 60 days after the President transmits the following fiscal year's budget to Congress; thus the current estimate in the December 31 annual SAR reflects the funding through the Future Years Defense Program (FYDP) and beyond, as well as the actual historical funding.

SAR data have limitations for use in studies of cost growth. Although these limitations have been discussed in detail elsewhere (Hough et al., 1992), we summarize some of them here (Arena et al., 2006):

1. SAR data are highly aggregated.
2. Baseline cost estimates change over time.
3. Cost information for future years reflects budget values and is not necessarily consistent with any particular cost estimate.
4. Reporting guidelines and requirements change over time.
5. Cost variances are often allocated inconsistently to SAR categories over time and between programs.
6. Program content reported by and estimated in the SARs is program-unique; thus SARs for similar program types may not cover similar program content.
7. Only programs meeting established funding thresholds or of special interest to Congress submit SARs.
8. The programmatic basis of SAR baseline estimates and current cost estimates is not explained.
9. Risk reserves, confidence levels, and uncertainty are not provided with SAR cost and schedule data.

Classifying Cost-Growth Variances

This study relies heavily on the data in the cost-variance section of each SAR. These data account for the difference in value of the current estimate for a program and its estimate from the prior SAR. The classification of these cost variances into causally oriented categories can be

extremely complex. While some cost changes are easily and transparently attributable to a specific cause, others are more difficult to classify. Current SARs report then-year dollar (or actual budgeted dollar) cost variance in the following categories (Past, 2007)[1]:

1. Quantity: cost variance resulting from a change in the number of end items being procured.
2. Schedule: cost variance resulting from a change in procurement or delivery schedule, completion date, or intermediate milestone for development or procurement.
3. Support: changes in program cost associated with training and training equipment, peculiar support equipment, data, operational site activation, and initial spares and repair parts.
4. Economic: cost variance resulting from price-level changes in the economy, including changes resulting from actual escalation that differs from that previously assumed and from revisions to prior assumptions of future escalation.
5. Engineering: cost variance resulting from an alteration in the physical or functional characteristics of a system or item delivered, to be delivered, or under development after establishment of such characteristics.
6. Estimating: cost variance due to correction of an error in preparing the baseline cost estimate, refinement of a prior current estimate, or a change in program or cost-estimating assumptions and techniques.
7. Other: changes in program cost due to natural disasters, work stoppage, and similarly unforeseeable events not covered in other variance categories.

The complete definitions of each category are given in Appendix D. These categories are somewhat causally oriented but do not make any attempt to differentiate between variances that occur through conscious decisions and those that could have been avoided through a

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[1] For comprehensive definitions of the SAR cost categories see DoD's *Consolidated Acquisition Reporting System (CARS) Users Guide*, p. 126.

better understanding of the system and what it would take to bring it to operational status.

Costs and cost variances in SARs are reported in both then-year (or budgeted) dollars and base-year (adjusted for inflation to a specific year's dollar buying power) dollars. In base-year variances, the economic category is not needed, because the effects of inflation over time are removed. Most base-year cost variances fall into the quantity, schedule, support, engineering, and estimating categories. The "other" category is used much less frequently.

Problems in Interpreting SAR Cost-Variance Data

Use of the cost-variance data from SARs is fraught with problems. Although reviews are performed by service headquarters and OSD, problems result from incomplete disclosure and explanations, which differ significantly in quality and completeness. These differences vary between programs and within any single program over time. The SAR format has evolved, and the SAR administrators (along with their leadership) also change over time. Complicating matters is the fact that SARs exist as a result of congressional direction; thus, they can be used as "report cards" for program management of DoD as a whole, or of individual services, or of individual programs. Although there is no way to understand the effect—if any—of the "report card" factor on program portrayal in the SARs, it does provide a strong incentive to portray programs and their challenges in the most positive light possible.

SAR authors also make errors of different types, some of which they correct in later SARs with or without specifically commenting on them. This complicates accounting for and allocating the cost variances. SARs often do not discuss technical or managerial problems in their executive summaries (or other narrative portions), thus further complicating determination of the source of a variance.

There are more-specific problems in the quantity and economic categories. Allocation of cost growth to a quantity change is generally underreported. The amount allocated to the quantity category is based

on the program unit-cost baseline reported in the SAR, not the SAR's current estimates. Changes in unit costs since that baseline, which contribute to the total cost effect of the quantity change, are reflected in the remaining cost-growth categories. To make matters worse, the baseline in the SAR is often not the same baseline from which cost growth is measured. This occurs when programs are rebaselined between major milestones, when programs have passed a major milestone subsequent to the one from which cost growth is measured, or when the baseline in the SAR is not coincident with events that generally represent a major milestone.[2] In addition, changes in support costs that are a direct result of quantity changes are routinely reported in the support category rather than in the quantity category.

In the economic category, disconnects between official inflation indices and actual experience can distort base-year dollar estimates. Updated indices published by OSD often result in the restatement of historical costs and changes to future costs in terms of base-year dollars when no change in then-year funding has occurred.

Moreover, although cost variances are generally identified with an explanation of their source, many of these explanations do not provide useful information. In some cases, ambiguity remains in determining the root cause of a cost variance even when all of the narrative portions of the SARs are used for context and explanation. Either the exact source of the growth is not identified or several different causes of cost variance are grouped together in a single variance category—often the estimating category—with no subdivision by value of the variance by sources. Finally, as noted above, some SARs contain errors that are corrected in later reports but not explained.

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[2] Public Law 10 USC 2432 (C)(1)(B) & (C) recently corrected the rebaselining problem between major milestones in program reporting by requiring SARs to use the original approved baseline. However, this does not affect past SARs, so the problem remains in the SARs used in this study.

Analysis of Programs

In spite of these limitations, the SARs do provide useful information for examining and tracking cost growth in selected programs. In this study, we used the following information:

1. Development and procurement cost estimates[3]
2. Cost variances by category from each SAR
3. Unit-cost calculations
4. Contract and procurement quantity information
5. Narrative discussions of events, program status, and updates.

For each program we created two files. The first is a narrative document that describes the nature and objective of the program, discusses its history and problems encountered during development and procurement, and examines key events or issues that had major influences on subsequent program cost growth. To create these files, we used the Mission and Description and Executive Summary sections of each SAR. These sections also provide explanations of some of the cost variances that were entered into the spreadsheet file for each program.

The second file is a spreadsheet that documents the key program milestones, tabulates the changing cost estimates for development and procurement, investigates unit costs and cost variances, and shows procurement quantities and costs as they changed throughout the life of the program. Spreadsheet files for each program include a history of the following items:

1. Program milestones and how and why they changed over time
2. Program costs and quantities
3. Unit costs for the program and procurement funding

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[3] SARs also report military construction and acquisition-related operations and maintenance (O&M) costs in programs with these types of funding. Military construction costs and variances were excluded because only nine of the 35 programs analyzed had appropriations of this type, rendering the calculation of averages not meaningful. None of the 35 programs included appropriations for O&M.

4. Cost variances for development and procurement, assigned to RAND and SAR categories
5. Program funding and quantities procured, by year
6. "Trigger events" that precipitated future cost and schedule growth.

This information is taken from the Schedule, Total Program Cost and Quantity, Unit Cost Summary, Cost Variance Analysis, and Program Funding Summary sections of the SAR. Some programs have two or more components. For example, the Longbow Apache helicopter improvement program had separate data for the airframe and the fire-control system. Where possible, we tracked the costs and cost variances separately. Finally, some programs are split during execution to create separate programs and SARs. This occurred in the F/A-18E/F program when the production for the EA-18G program was taken out of that planned for the E/F model. We typically track the two pieces of the original program as separate programs—as is done in the SARs.

All costs are recorded in the program's original base-year dollars— that is, whatever base year was used at the program's MS B. When the program progresses to MS C, many SARs change the base-year dollars. In the spreadsheet files, we converted these estimates and variances to original base-year dollars, using the program-unique conversion factors identified in that SAR for that program. This provides consistency from MS B throughout the duration of the system acquisition.

Cost-variance values are taken directly from the Cost Variance Analysis section of each SAR. The SARs assign cost variances in the different appropriations to categories, normally with an explanation of the issue or activity that created the variance. The narrative associated with each value is used as the primary determinant for assigning that value to one of the RAND variance categories.

Cost-Variance Categories

Using the available cost information, we identified cost variances and sorted them into a consistent set of categories. While the SAR vari-

ance categories focus on financial areas, our categories are oriented toward *sources* of cost growth. Determining the most appropriate set of cost categories for this analysis was challenging, because the categories needed to meet a number of criteria to the maximum extent possible:

1. They should apply to development and procurement costs in all programs.
2. They should be as distinct as possible, to minimize data-assignment ambiguities, given the limitations of the data.
3. They should be comprehensive, so that all cost variances can be assigned to one of them, given the limited information available in the SARs.
4. They should be identified with potential policy levers that could be used to limit future cost growth.

We explored several sets of cost categories during the study and found problems with all of them. Our final set of categories meets the criteria better than any of the other sets but is less than ideal for determining causes of growth and thus might be improved in expanded future work. It consists of the following major categories: (1) errors in estimation and planning, (2) decisions by the government, (3) financial matters, and (4) miscellaneous sources. The subcategories within these categories are shown in Tables 2.5 through 2.8, with examples from selected programs. As we will discuss later, it was sometimes difficult to assign costs and variances uniquely to specific subcategories.

Table 2.5
Subcategories in the Errors Category

Subcategory	Example
Cost estimate: inaccurate estimate of costs to meet system requirements as defined at MS B	Revised engineering man-hours and contract cost for C-17 (1988)
Schedule estimate: inability to conform to program schedule in meeting system requirements as defined at MS B	Extension of Javelin development schedule by 18 months (1991)
Technical issues: unanticipated technical problems in meeting requirements as defined at MS B	Modification to the Mobile Gun System variant of the Stryker to meet mission equipment-package armor specifications (2004)

Table 2.6
Subcategories in the Decisions Category

Subcategory	Example
Requirements: government-changed requirements following MS B	Increased requirements for self-defense and simulation systems for JSTARS (1988)
Affordability: decisions by the government to change the program's funding because of external-to-the-program priorities (reprogramming decisions)	Budget reduction in Titan IV Centaur stage program (1986)
Quantity: increased or reduced number of units in development or procurement	Reduction in OH-58D procurement (1989)
Schedule: extension or contraction of program schedule for reasons other than poor original planning	Reduced production rate and extended schedule for MM III GRP (1988)
Inter- and intraprogram transfers: color-of-money changes or transfers of funding and associated work	Transfer of funds from Wideband Gapfiller Satellite (WGS) to support future wideband programs (2001)

Table 2.7
Subcategories in the Financial Category

Subcategory	Example
Exchange-rate changes	Engine costs for the T-45 Training System (1998)
Inflation-rate changes	Adjustment for current and prior escalation in the F-22 (2005)

Table 2.8
Subcategories in the Miscellaneous Category

Subcategory	Example
Error corrections	"Adjustments" made to balance in the SMART-T program (1998)
Unidentified variances	Aggregate variance in the B-1B Conventional Munitions Upgrade Program (JDAM portion) in the first year after its MS B (1995)
External events	Effect of the Challenger disaster on Titan IV program (1986)

The categories in Table 2.5 consist of the errors of program participants: the program officers and their advisors, the prime contractor(s), and/or associate contractors. Inaccurate estimation of costs occurs either in the initial plan or during the course of the program when

scope changes or the program plan is revised without an associated change in the system's required performance. Cost analysts produce estimates for acquisition programs based on programmatic and technical inputs from many communities within DoD and the weapon-system contractors. In addition, at MS B and at major program plan revisions thereafter, enormous pressure can be placed on the cost analysts to create optimistic estimates so that the proposed program will not be viewed as too expensive to move forward as currently specified. Cost-estimating errors thus can result from use of incorrect cost data or models, inaccurate engineering estimates, or unrealistically optimistic assumptions regarding the activities required, the time, and the resources needed to bring the system to operational status.

Schedule-estimate errors result from the inability to conform to the initial program schedule or to the revised schedules, again without an associated change in the required system performance.

Technical-issue errors result from unanticipated technical problems encountered in achieving the required system performance as defined at MS B. Technical problems ultimately increase program costs and almost certainly cause schedule slips, but when possible, we assign these variances to this category to isolate cost growth due to underlying technical problems from that caused by poor direct estimates of cost and schedule.

The categories in Table 2.6 consist of decisions made by the government—the program office, the lead service, DoD, or the President and Congress during the PPBS (planning, programming, and budgeting system) process, the authorization process, and the appropriations process. They include changes in the requirements—i.e., capabilities or supportability—of a system at any point after MS B. In most cases, these changes add capabilities to the system and increase costs. Requirements changes often take the form of preplanned product improvement (P3I) programs for systems that are developed and procured over long time periods. Added requirements tend to induce subsequent cost-estimate, schedule-estimate, and technology issues that ultimately increase costs. The resulting variances are placed in the requirements category, the one that best describes their underlying cause.

Requirements are occasionally scaled back without associated cost avoidance (or savings) being reported. This typically occurs at the time of a program rebaseline, during the major development phase, or when some maturing system components are not providing the required capability. If the anticipated performance of such components is close to that originally specified, a decision is often made to slightly relax the original requirement rather than incur additional cost and schedule slippage to achieve the original specification. The effect of relaxing requirements without reporting associated cost avoidance is the underestimation of the cost to meet the original requirement. SARs have a section (which is usually classified) documenting basic system-performance characteristics at an aggregate level. Data observed over time from that section allowed us to observe this problem. We suspect that more-detailed performance data would provide additional evidence of the problem, but such data are not provided in SARs.

The affordability subcategory includes cost-estimate changes resulting from reasons not associated with requirements. These changes typically involve reprogramming that shifts funding or leaves the program with less funding within the FYDP. Some higher authority—the service, OSD, Congress, or the President—typically makes these decisions. Affordability variances tend to be small, but they can add up over time. They are usually initially accounted for as cost savings, because funding is taken from the program. Affordability changes can also be positive—for example, when a previously unfunded requirement is funded.

Changes in quantity occur when the government decides that the proposed quantity is too expensive and must therefore be cut, that more system units are required, or that the initial or current quantity is no longer justifiable, for any number of reasons. Cost growth associated with units transferred between program phases—typically between development and procurement—is included in this subcategory, as are support-item quantity changes and other program changes associated with changes in the number of primary items. While quantity changes could also be reasonably described as a form of requirements change, we chose to report them in a separate category because normalizing

for quantity changes (as is done in most other cost-growth studies) excludes them as a source of cost growth.

The schedule subcategory is used for growth due to deliberate schedule changes, such as a shortened schedule to develop or produce the desired system more quickly or an extended schedule to stretch out the development or procurement phases. Schedule stretches resulting from decisions to reduce annual funding in aggregate (development plus procurement) or declining short-run demand for the system also fall into this category. Schedule changes resulting from technical problems or from moving funding to cover cost growth in other portions of the program do not fall into this category, as these are error-related.

Finally, inter- or intraprogram transfers include transfers between program phases as well as funding, along with the associated work scope into or out of a program. This usually occurs because the work belongs in a new program or reorganization of activities moves it to another area. These variances do not represent "true" cost growth in either an estimating sense (the change in the program's expected cost is not a reflection on the accuracy of the MS B cost estimate) or a budgeting sense. From a broader perspective, the transfer between program phases is a zero-sum event because it is only a "color-of-money" change and has no effect on the total funding ultimately needed to meet the required capability. When content and funding are moved to a different program or phase, no real cost change per se should occur if the two are properly matched.

Cost growth in the remaining categories, shown in Tables 2.7 and 2.8, is either beyond the control of the cost-estimation community, program management, and other government entities or simply does not originate from an error or decision.

The financial category includes changes in exchange rates and in inflation level. Exchange rates are relevant only for programs in which a major portion of the system is built in a foreign country. This was the case in only one of the 35 programs examined in this study, but as the industrial base of U.S. weapon-systems manufacturers globalizes, more programs will experience variances from this source. Inflation-rate changes affect all programs, as it is impossible to precisely predict price-escalation levels.

The miscellaneous category includes corrections of reporting errors, unidentified cost variances, and external events. SAR reporting errors are different from acquisition-management errors in estimating costs, schedules, and technical challenges. SAR reporting errors are specified as such and result from mistakes made in preparing a program's prior SARs. In most cases, these errors are corrected in later SARs, but occasionally the corrections do not completely account for all the variance. When this occurs, it is impossible to allocate the remaining cost variance to the other categories; thus, they fall into the error-corrections subcategory.

Unidentified variances are cost variances that are overlooked between SARs, i.e., they are not shown in one SAR but appear without explanation in the subsequent SAR. This sometimes occurs when a program is split off from another program.

External events are circumstances that affect a program but are not a result of program activities or issues. Just two of the 35 programs in our sample recorded cost variances resulting from external events. The single largest contributor was the Challenger disaster, which caused major changes to the Titan IV launch-vehicle procurement.

Mapping of SAR Variance Categories

For each program, we used the narrative, schedule, and cost data to track development and procurement cost growth over time. The RAND cost-growth subcategories are mapped to the SAR categories in Table 2.9. The mapping is straightforward for some categories, but not for others. The table shows the complexity of taking the data in the seven SAR categories and redirecting those data into the more-robust RAND category set. The SAR quantity category maps only into the RAND quantity and miscellaneous categories. The SAR schedule category maps into seven RAND subcategories. The SAR support and estimating categories map into almost every RAND subcategory, illustrating their broad utilization in the SARs. Most of the items in the SAR economic category are allocated to RAND's inflation subcategory, with occasional allocations to additional RAND subcategories.

Table 2.9
Mapping of SAR Variance Categories to RAND Categories

RAND Cost-Growth Category	SAR Variance Category						
	Quantity	Schedule	Support	Economic	Engineering	Estimating	Other
Estimation and planning errors							
Cost estimation			X		X	X	
Schedule estimation		X	X		X		
Technical issues		X			X	X	
Decisions							
Requirements			X		X	X	
Affordability			X	X		X	
Quantity	X	X	X	X	X	X	
Schedule		X	X		X	X	
Program transfers			X			X	
Financial							
Exchange rate				X		X	X
Inflation			X	X		X	X
Miscellaneous							
Error corrections	X	X	X	X	X	X	X
Unidentified variances	X	X	X	X	X	X	X
External events	X	X	X		X	X	X

SAR engineering variances map primarily into the RAND requirements or technical-issues subcategories, but some map into others.

Problems in Categorizing Cost Growth

The RAND approach to categorizing cost variances presents some challenges. Our aim is to identify and separate cause and effect. In a situation where a program schedule is modified and costs are subsequently higher, we attempt to determine whether cost growth caused the schedule change or the schedule change resulted in cost growth. When a technical issue makes it impossible to meet the original schedule and cost, the original cost and schedule estimates were most likely inadequate in that they failed to account for the issue.

Externally imposed budget reductions can be a reaction to cost or schedule problems within the program (belonging in the errors category) or can be completely unassociated with the program's cost and schedule performance (belonging in the decisions category). Externally imposed funding reductions often result in a program replan that requires additional resources and time over the long run to field the system. When the replan is precipitated by problems within the program, the reaction—budget cuts in the short term—adds to ultimate cost growth and causes schedule slips. The reaction to the program's initial problem ultimately compounds the cost growth. It can be difficult to disentangle the portion of the growth that is due to errors from the portion that is caused by decisions.

Another complicating factor is the rebaselining of plans for the remainder of a system's acquisition. A program may produce a revised plan for the remaining execution of development and production that includes updated cost, schedule, and performance specifications for providing the desired capabilities. Such rebaselining does not create a problem with our cost-variance categorization scheme if the program's requirements do not change substantially. However, if the requirements change substantially, the variances associated with the rebaselining may underreport cost growth in the errors category (and put it in the

decisions category). This misallocation occurs because difficulties that were not previously acknowledged and accounted for as cost variances are now incorporated into the new baseline. This approach to program rebaselining is commonly referred to in the acquisition community as "getting well."

On rare occasions, rebaselining results in "lost" variances—changes in the program estimate that are not explained. This occurred in a few programs when the annual SARs were suspended in early 2001 by the Bush administration. No program SARs were prepared with the date of December 2000. As a result, many programs went two full years without a SAR. One possible explanation for the lack of continuity of estimates at that time was program management's expectation that SARs would never again be required, which could have led to the discontinuation of tracking the reasons for changes in estimates.

The implication of rebaselining for our cost-variance allocation scheme is that within the variances reported as part of a program rebaseline, we may have poor insight into which portion of cost growth and schedule slips is associated with the original system capabilities and which portion is associated with the added requirements. A careful review of the 35 mature programs in this study showed some ambiguity in the description of cost variances occurring at the time of rebaselines. We used our best judgment to categorize variances of significant uncertainty, and there is little probability that in any single program the magnitude of the uncertain variances was large enough to cause an overall misrepresentation of the primary causes of cost growth.

SARs vary significantly in how well they report technical and other problems. In many cases, technical issues are never discussed in the narrative sections, and cost and schedule problems are itemized but not clearly explained. A cost variance of $50 million assigned to estimating in the SAR may have three or four different causes that are not discussed in sufficient detail to distribute the variance among them.

We could cite many more specific issues, but these examples illustrate the difficulty of assigning cost variances to categories. It requires judgment, can be quite uncertain, and is somewhat inherently subjective. Despite these problems, we feel that our in-depth analysis,

thorough background research on program histories, and new categorization allow for meaningful and consistent comparisons among programs.

Cost Growth in Selected Programs

In this chapter, we present the results of our analysis. We begin by describing alternative ways to examine the data: weighted and simple averages, medians, etc. We then focus on our analytic results, using simple averages. After showing the total of development plus procurement cost growth for all programs, we present a breakout by development and procurement budget categories. We then compare our results with the total cost growth as reported in the SAR variance categories. Following this comparison, we show the distribution of cost growth, broadening the presentation of data beyond simple averages. We next analyze cost growth for the Air Force–sponsored programs in our sample and compare it to cost growth in the non–Air Force programs. Finally, we examine cost growth by system type (i.e., aircraft, missile, and electronics).

Presentation of Data

There are several ways to represent cost-growth data. One way is to show growth by category, using weighted averages, which involves aggregating costs from groups of programs. Every program has a base year, normally the year in which the system entered full-scale development at MS B. At that time, the Defense Acquisition Authority adopts a development baseline estimate for costs over the program's entire acquisition. Because of inflation, costs for programs with different base

years cannot be directly combined. To combine costs for a portfolio of programs, each program's figures must be converted to a common base year.

In weighted-average cost growth, larger programs have a greater influence on the outcome; thus the calculation can provide results that are markedly different from those obtained by using a simple-average approach. Analyzing cost growth in aggregate may be desirable for trying to understand or control the total cost growth of a portfolio of programs and its effect on defense spending. If a single program costs far more than the average of the others, controlling its costs will be more important from the overall budget standpoint. Cost growth in a large program may overwhelm cost savings in a number of other, smaller programs. The results obtained using weighted cost-growth factors are presented in Appendix B and indeed are markedly different from the results derived with the simple-average method.

The weighted-average approach does not give the analyst much insight into why cost growth occurs in individual programs. For that purpose, it is better to use simple averages, converting the results for each program into percentage growth by appropriation and category. This approach, which focuses the analysis on the growth in development and procurement of individual programs, is consistent with the approach used by Arena et al. (2006) and is used in this chapter.

As noted in Arena et al. (2006), the distribution of cost-growth figures from a sample of programs tends to be log-normal. As a result, growth is not symmetrically distributed around an average value. A few programs have historically had very large cost growth with respect to the mean. This results in a high-cost-growth "tail." The distribution of cost-growth values for various programs was shown in Figure 1.1. Because of the non-normal shape of the cost-growth distribution, it is important to characterize the full distribution, which we do by using medians and percentiles.

Multiservice Program Sample

Total Cost Growth

Average growth in total program costs for development and procurement relative to the MS B baseline cost estimate in the 35 mature programs in our sample is shown in Table 3.1.[1] It is clear that the decisions category accounts for most of the cost growth. Decisions cause, on average, more than two-thirds of the total growth in the 35 programs. Errors accounted for about one-quarter of cost growth. The financial and miscellaneous categories combined account for only one-sixteenth of the total growth, or just 3.8 percent in aggregate.

Table 3.1
Total Cost Growth for 35 Sample Programs
(mean values)

Cost Growth Category	Total Cost Growth (%)
Errors	14.6
Cost estimate	10.1
Schedule estimate	0.9
Technical issues	3.5
Decisions	41.6
Requirements	12.9
Affordability	−1.3
Quantity	21.9
Schedule changes	8.9
Inter- or intraprogram transfers	−0.7
Financial	1.4
Exchange rate	0.1
Inflation	1.3
Miscellaneous	2.4
Error correction	−0.4
Unidentified	−0.4
External events	3.1
Total	60.0

NOTE: Due to rounding, subcategory totals may not sum exactly to category or overall totals in this and all subsequent tables in this chapter.

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[1] Nine of the 35 programs had military construction funding that was not included.

The total cost-growth figure of 60 percent compares quite well to the figure in the previous RAND study of completed programs (Younossi et al., 2007), where it was observed that total cost growth was found to be 46 percent from the MS B baseline. However, that value was adjusted for quantity changes. If we remove quantity changes from the total growth shown in Table 3.1 (almost 22 percent), we obtain a total growth of only 38 percent. The fact that this sample has a somewhat lower growth should not be surprising, because some of the programs are incomplete and most likely will experience additional cost growth before completion.

Development and Procurement Cost Growth

Table 3.2 shows cost growth for development and procurement in our sample programs. Development cost growth averages 57 percent, and procurement cost is even higher, averaging 75 percent. Most prior studies find the opposite—that development cost growth is substantially higher then procurement cost growth. Our results differ because we do not normalize for quantity changes in procurement, which, at 41 percent, accounts for more than half of the 75 percent. If we exclude quantity changes, our result changes to 34 percent for procurement cost growth, making it consistent with the findings of prior studies.

Of the four major categories, decisions dominate the overall growth in both development and procurement. For development, decisions account for 31 percent of the 57 percent cost growth; for procurement, they account for 57 percent of the 75 percent cost growth.

Errors are the second largest cost-growth contributor in both development and procurement. For development, errors account for 20 percent of the 57 percent cost growth. For procurement, they account for 15 percent of the 75 percent cost growth. The financial group is a relatively minor contributor to cost growth in both development and procurement. The miscellaneous group is noteworthy in development at 5 percent but only a minor contributor to procurement at 1 percent.

It is interesting to note that growth due to cost-estimating errors is much higher for development than for procurement. This indicates the overall greater difficulty of accurately estimating development activities and their related costs. Another interesting difference is that the

Table 3.2
Development and Procurement Cost Growth for Sample Programs (mean values)

Cost-Growth Category	Development Cost Growth (%)	Procurement Cost Growth (%)
Errors	19.6	14.7
Cost estimate	18.0	8.4
Schedule estimate	1.0	0.9
Technical issue	0.6	5.4
Decisions	30.7	57.4
Requirements	17.5	9.5
Affordability	−1.9	−0.5
Quantity	4.3	40.8
Schedule changes	6.0	10.0
Inter- or intraprogram transfers	4.8	−2.4
Financial	1.0	1.8
Exchange rate	0.1	0.1
Inflation	0.9	1.7
Miscellaneous	5.2	1.4
Error correction	−0.5	−0.3
Unidentified	−0.3	−0.3
External events	6.0	2.1
Total	56.5	75.4

growth due to technical issues arises mainly in procurement, possibly because these issues become more apparent during the procurement phase of a program. Growth due to requirements changes is much greater in development.

In an earlier study, McNicol (2004) also explored weapon-systems cost growth by categorizing growth causes and similarly found most growth broadly attributable to "mistakes" and "decisions." However, that study and this study are quite different in design and therefore are not well suited for comparison. McNicol's analysis covered only procurement costs, while this study covers both development and procurement. Moreover, McNicol examined four times as many programs as we did. To attain such a large sample, McNicol included program types that we excluded (ships and submarines) and, more important, included fewer (as a fraction of the total) mature programs. He

included programs that were three years or more past their MS B date. Programs in development or early production made up the majority in his data set. The programs in the present study were at a minimum 64 percent complete in development and 40 percent complete in procurement; about three-fourths of them were at least 90 percent complete in development and 70 percent complete in procurement. Finally, McNicol normalized his program data for quantity changes, whereas we did not.

Comparison to SAR Cost Categories

The results using the SARs categories for our 35 sample programs are shown in Table 3.3. Comparison of Table 3.3 with Tables 3.1 and 3.2 indicates that for development costs, the two assignment schemes provide somewhat different results. The SAR categorization assigns the vast majority of cost growth to estimating and engineering; more than half of development cost growth is allocated to estimating. Small increases are shown in the schedule and quantity categories, while the remaining categories account for less than 1 percent. The SAR engineering category is generally reserved for changes in requirements, and the costs allocated to it generally agree with our assignment to requirements. The growth allocated to the SAR schedule category is less than half the amount we show for growth related to both schedule errors and

Table 3.3
Contribution to Cost Growth, by SAR Variance Category, for 35 Sample Programs

Category	Total (%)	Development (%)	Procurement (%)
Economic	0.1	0.3	0.0
Engineering	13.3	18.6	11.9
Estimating	17.5	30.0	12.2
Quantity	19.8	2.6	38.6
Schedule	4.2	4.5	4.9
Support	5.5	0.9	8.4
Other	−0.4	−0.4	−0.7
Total	60.0	56.5	75.4

schedule decisions. Our higher value results from the inclusion of indirect effects of schedule changes, which the SARs place in the estimating and support categories. Finally, some of the growth in the SARs estimating category appears in our program-transfers subcategory.

For procurement, the SARs distribute cost growth primarily to quantity, estimating, and engineering. Smaller contributions to growth are attributed to schedule and support, and some savings are attributed to "other." In contrast, we allocated most of the procurement cost growth to quantity, with substantial growth coming from schedule, requirements, and cost-estimating errors. Although the results for the SAR quantity category seem similar to RAND's results for the same category, this is more accidental than a reflection of similarity in definition. Our categorization of quantity cost growth includes both the costs the SARs place in the estimating category (e.g., those costs associated with production units not in the original plan) and growth in the support category that is related to changes in quantity. We include some costs in the RAND schedule decisions subcategory that the SARs allocate to estimating (particularly costs associated with production rate changes). The SAR approach, in general, tends to overallocate cost variance to the estimating category. Our approach results in less cost-estimating growth, with some of the growth attributed to technical issues.

Distribution of Cost Growth

We obtained a better idea of the potential range of cost growth by examining the distributions for each category. The results are shown in Tables 3.4 through 3.6 for development, procurement, and total cost, respectively. In each table, we show the mean, median, 10th, 25th, 75th, and 90th percentile values.[2]

As shown in Table 3.4, median values are roughly half or less of their corresponding mean values, demonstrating the extent of the high-

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[2] The values for the subcategories for each percentile do not sum to the total for the category. This difference arises because different programs are represented in each column—e.g., at the 10th percentile, the figure from, say, program X represents cost errors; the figure from, say, program Y represents schedule errors; and the figure for inappropriate estimates in aggregate (including both cost and schedule) could be from program X, Y, or Z.

Table 3.4
Distribution of the Contributions to Development Cost Growth for 35 Sample Programs (in percent)

Category	Mean	10th Pct	25th Pct	Median	75th Pct	90th Pct
Errors	19.6	−6.6	−1.2	10.7	32.1	61.5
Cost estimate	18.0	−8.4	−2.0	9.2	27.0	61.2
Schedule estimate	1.0	0.0	0.0	0.0	0.0	2.1
Technical issues	0.6	0.0	0.0	0.0	0.0	1.1
Decisions	30.7	−2.5	0.0	16.8	43.2	76.1
Requirements	17.5	0.0	0.0	11.5	34.3	44.6
Affordability	−1.9	−10.2	−3.4	0.0	0.0	4.3
Quantity	4.3	-0.3	0.0	0.0	0.0	8.6
Schedule changes	6.0	0.0	0.0	0.0	8.8	22.6
Inter- or intra-program transfers	4.8	−3.4	0.0	0.0	5.6	15.1
Financial	1.0	−1.6	−0.2	0.5	1.3	2.7
Exchange rate	0.1	0.0	0.0	0.0	0.0	0.0
Inflation	0.9	−1.6	−0.5	0.4	1.3	2.7
Miscellaneous	5.2	−0.2	0.0	0.0	0.0	0.0
Error correction	−0.5	0.0	0.0	0.0	0.0	0.0
Unidentified	−0.3	0.0	0.0	0.0	0.0	0.0
External events	6.0	0.0	0.0	0.0	0.0	0.0
Total	56.5	−5.8	5.8	33.7	81.8	132.6

cost-growth tail in the distribution for every category. The distributions' skew to the right results from extreme cost growth in relatively few programs. Mean development cost growth is about 57 percent. Ten percent of the projects had greater than 130 percent development cost growth, and 10 percent had 5 percent or more negative development growth. For development growth caused by errors, the mean was about 20 percent, with the middle 80 percent of the programs having development cost growth due to errors of between about –7 percent and 62 percent. The average development cost growth caused by government decisions is larger, but one-fourth of the programs had no decision-related development cost growth.

Table 3.4 also suggests a further limitation of our analysis. The median-value column indicates that development cost growth is predominately attributed to two main sources, cost-estimating errors and

Table 3.5
Distribution of the Contributions to Procurement Cost Growth for 35 Sample Programs (in percent)

Category	Mean	10th Pct	25th Pct	Median	75th Pct	90th Pct
Errors	14.7	−39.8	−4.4	6.9	29.3	60.9
Cost estimate	8.4	−41.0	−6.2	2.2	25.9	51.0
Schedule estimate	0.9	0.0	0.0	0.0	0.0	1.5
Technical issues	5.4	0.0	0.0	0.0	2.1	16.3
Decisions	57.4	−29.6	−6.2	16.2	76.5	154.7
Requirements	9.5	−4.0	0.0	3.3	16.9	32.1
Affordability	−0.5	−4.4	−1.5	0.0	0.0	3.1
Quantity	40.8	−37.5	−14.3	3.2	44.9	147.8
Schedule changes	10.0	−0.2	0.0	4.0	14.5	25.5
Inter- or intra-program transfers	−2.4	−7.8	−4.7	0.0	0.0	0.8
Financial	1.8	−0.4	0.2	1.0	2.0	5.3
Exchange rate	0.1	0.0	0.0	0.0	0.0	0.0
Inflation	1.7	−0.4	0.2	0.8	1.8	5.3
Miscellaneous	1.4	−1.3	0.0	0.0	0.0	0.0
Error correction	−0.3	−0.3	0.0	0.0	0.0	0.0
Unidentified	−0.3	0.0	0.0	0.0	0.0	0.0
External events	2.1	0.0	0.0	0.0	0.0	0.0
Total	75.4	−39.1	−3.0	34.8	89.7	202.7

requirements decisions, with each contributing nearly equally to the growth. Most of the other categories have a zero value. These results suggest that the SARs report cost growth in a very simplified way, showing only one or two sources of growth when growth does occur. In reality, cost growth is more complex, with smaller contributions from other sources. Regardless of whether mean or median values are used, the results indicate that in most programs, the majority of the development cost growth is due to estimating errors and requirements changes.

Table 3.5 suggests that variability in procurement cost growth attributed to errors or decisions is greater than that in development cost growth. At every percentile point, procurement errors are less than development errors. This suggests that development cost growth is more difficult to contain, a conclusion with which the cost-estimating community would most likely concur.

Table 3.6
Distribution of the Contributions to Total Cost Growth for 35 Sample Programs (in percent)

Category	Mean	10th Pct	25th Pct	Median	75th Pct	90th Pct
Errors	14.6	−11.0	−3.3	7.3	20.6	44.0
Cost estimate	10.1	−18.2	−5.6	5.1	19.8	41.4
Schedule estimate	0.9	0.0	0.0	0.0	0.0	4.2
Technical issues	3.5	0.0	0.0	0.0	1.7	13.1
Decisions	41.6	−17.5	−3.6	26.1	65.4	91.9
Requirements	12.9	−1.1	0.3	5.6	13.1	34.6
Affordability	−1.3	−5.9	−1.7	−0.3	0.0	3.3
Quantity	21.9	−33.2	−7.8	3.1	34.1	75.3
Schedule changes	8.9	−0.2	0.3	3.2	14.6	21.9
Inter- or intra-program transfers	−0.7	−5.1	−0.5	0.0	0.3	2.4
Financial	1.4	−0.3	0.0	0.8	1.6	4.6
Exchange rate	0.1	0.0	0.0	0.0	0.0	0.0
Inflation	1.3	−0.3	0.0	0.7	1.6	4.3
Miscellaneous	2.4	−1.4	0.0	0.0	0.0	0.2
Error correction	−0.4	−0.3	0.0	0.0	0.0	0.0
Unidentified	−0.4	0.0	0.0	0.0	0.0	0.0
External events	3.1	0.0	0.0	0.0	0.0	0.0
Total	60.0	−18.4	2.7	32.0	60.0	139.5

Decision-related cost growth for procurement is essentially equal to that for development in the modal program. However, the variability both above and below the modal program is far greater in procurement than in development, indicating a much larger willingness to exercise discretion in changing procurement plans and the resulting cost than is the case in development. This observation is consistent with the scenario in which events that ultimately cause cost growth occur after much of the development money has been spent, so that the resulting cost growth does not appear until the procurement phase.

As in development, median values are roughly half or less of their corresponding mean values. In procurement, 10 percent of the programs had cost growth from errors greater than 60 percent, while more than 25 percent had negative procurement cost growth associated with errors. Similarly, for decision-related procurement cost growth,

10 percent had procurement cost growth greater than 150 percent, but more than 25 percent had negative procurement cost growth. As the table also shows, this result occurs primarily because of changes in procurement quantities.

Unlike the results for development cost growth, the median procurement cost-growth values indicate that the reported causes for growth are distributed among more categories; specifically, we see contributions from schedule and quantity decisions, along with a smaller contribution from financial issues. As in development, decisions are the dominant cause of cost growth.

Table 3.6 shows the total-cost-growth distributions. The procurement portion is dominant, since procurement accounts for about three-quarters of the dollars spent in a typical program. As seen in development and procurement, median values for the sum of the two are roughly half or less than mean values. About 25 percent of the programs had 3 percent or less total cost growth, and another 25 percent had total cost growth greater than 60 percent. That 60 percent is the same as the mean value for the dataset, showing just how extreme cost growth is in the 25 percent of programs with the highest levels.

Mean errors in cost estimation averaged about 10 percent, whereas the median was approximately 5 percent. The 90th-percentile values again indicate how extreme total cost growth can be—over 140 percent. As in our observations for development cost growth, few programs report cost growth due to technical or schedule errors.

Comparison of Cost Growth in Air Force and Non–Air Force Programs

After the analysis of the 35-program sample was well under way, the project sponsor asked RAND to examine the Air Force program subset separately. The results for the 16 Air Force programs are given in Table 3.7, and those for the 19 non–Air Force programs are given in Table 3.8. The tables show interesting differences in cost growth.

Table 3.7
Sources of Cost Growth for 16 Air Force Programs (mean values)

Category	Development Cost Growth (%)	Procurement Cost Growth (%)	Total Cost Growth (%)
Errors	14.7	21.7	16.1
Cost estimate	13.5	14.3	11.2
Schedule estimate	0.7	1.7	1.5
Technical issues	0.5	5.7	3.5
Decisions	32.8	66.7	41.9
Requirements	17.7	4.4	9.3
Affordability	−3.5	−0.9	−2.3
Quantity	3.8	54.5	25.4
Schedule changes	9.5	12.0	11.4
Inter- or intra- program transfers	5.3	−3.4	−1.8
Financial	0.6	1.6	1.2
Exchange rate	0.0	0.0	0.0
Inflation	0.6	1.6	1.2
Miscellaneous	12.3	4.6	6.4
Error correction	0.0	0.0	0.0
Unidentified	−0.8	0.0	−0.5
External events	13.0	4.6	6.9
Total	60.5	94.6	65.6

Hypothesis testing of these differences shows that they are not statistically significant at the 95 percent confidence level.[3] In a similar comparison, Arena et al. (2006) found no significant differences in cost growth among the services. We additionally tested for statistically significant differences at the category level, and none were found. The high standard deviations and relatively small sample sizes explain why the observed differences, which appear significant to the casual observer, are not so when basic statistical tests are applied.

Despite the statistical insignificance of the differences between Air Force and non–Air Force programs, interesting relative differences in cost growth are worthy of note. For development on the whole, cost

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[3] The hypothesis testing was not statistically significant for any mean value at the total, category, or subcategory level, even when the confidence level was lowered to 90 percent. Only one of 13 T-tests scored higher than 1.16.

Table 3.8
Sources of Cost Growth for 19 Non–Air Force Programs (mean values)

Category	Development Cost Growth (%)	Procurement Cost Growth (%)	Total Cost Growth (%)
Errors	23.7	8.9	13.2
Cost estimate	21.8	3.5	9.3
Schedule estimate	1.2	0.2	0.4
Technical issues	0.7	5.2	3.6
Decisions	29.0	49.7	41.4
Requirements	17.3	13.8	15.9
Affordability	−0.5	−0.1	−0.5
Quantity	4.7	29.3	18.9
Schedule changes	3.1	8.2	6.9
Inter- or intra-program transfers	4.4	−1.6	0.3
Financial	1.3	1.9	1.6
Exchange rate	0.2	0.2	0.2
Inflation	1.2	1.7	1.3
Miscellaneous	−0.8	−1.2	−0.9
Error correction	−0.9	−0.6	−0.7
Unidentified	0.1	−0.6	−0.2
External events	0.0	0.0	0.0
Total	53.2	59.2	55.3

growth is higher in Air Force programs: 60 percent versus 53 percent. Development cost-estimating errors are lower in Air Force programs, 14 percent versus 22 percent. Schedule changes driven by decisions are higher in Air Force programs, 9 percent, compared with 3 percent in the non–Air Force programs. All other categories except the miscellaneous category show similar cost-growth values.

The largest difference in development occurs in the miscellaneous category, where Air Force programs average 12 percent, while non–Air Force programs average a negative 1 percent. This difference is driven by a single event in a single program. The redesign of the Titan IV launch vehicle that was a direct result of the Challenger disaster in 1986 caused more than 200 percent cost growth in that program's development baseline estimate. Had this disaster not occurred, average cost growth in the miscellaneous category of development for Air Force programs would be equal to that for non–Air Force programs.

The 13 percent reduction in the development total for Air Force programs would reduce that total to 47 percent, less than the average for development in the non–Air Force programs. This discussion illustrates why the observed differences between cost growth in the Air Force and non–Air Force programs are not statistically significant.

Total procurement cost growth is much higher in the Air Force programs, 95 percent versus 59 percent. This 36 percent difference is completely explained by differences in two categories: Cost-estimating errors amount to 14 percent in the Air Force programs, compared with just 3 percent in the non–Air Force programs, and decisions on quantity amount to 55 percent in the Air Force programs, compared with 29 percent in non–Air Force programs.[4] Results in most of the remaining categories are similar or slightly higher in the Air Force programs, with the exception of decisions in requirements, which total 4 percent in Air Force programs and 14 percent in non–Air Force programs.

Tables 3.9 and 3.10 present the distribution of results for total cost growth for the Air Force programs and non–Air Force programs, respectively.

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[4] The difference in cost-estimating errors is 11 percent (14 percent less 3 percent), and that in the decisions on quantity is 26 percent (55 percent less 29 percent). Adding these, we obtain 37 percent, which is about equal to the 36 percent difference in the totals of the two.

Table 3.9
Distribution of Total Cost Growth for 16 Air Force Programs
(mean values, in percent)

Category	Mean	10th Pct	25th Pct	Median	75th Pct	90th Pct
Errors	16.1	−5.5	3.3	13.9	20.2	31.9
Cost estimate	11.2	−7.2	−0.9	9.0	17.6	26.4
Schedule estimate	1.5	−0.1	0.0	0.0	1.2	5.7
Technical issues	3.5	−0.2	0.0	0.0	1.8	12.7
Decisions	41.9	−15.5	−3.7	15.0	45.0	75.2
Requirements	9.3	−1.4	−0.1	4.3	8.8	23.3
Affordability	−2.3	−7.3	−4.7	−0.6	0.1	2.5
Quantity	25.4	−36.8	−4.2	0.3	25.7	70.8
Schedule changes	11.4	0.0	0.8	7.2	18.0	24.3
Inter- or intraprogram transfers	−1.8	−8.8	−1.9	−0.1	0.1	0.4
Financial	1.2	−0.3	0.4	0.7	1.1	3.7
Exchange rate	0.0	0.0	0.0	0.0	0.0	0.0
Inflation	1.2	−0.3	0.4	0.7	1.1	3.7
Miscellaneous	6.4	0.0	0.0	0.0	0.0	1.0
Error correction	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified	−0.5	0.0	0.0	0.0	0.0	0.0
External events	6.9	0.0	0.0	0.0	0.0	1.0
Total	65.6	−18.3	−6.3	44.1	60.6	133.5

Table 3.10
Distribution of Total Cost Growth for 19 Non–Air Force Programs
(mean values, in percent)

Category	Mean	10th Pct	25th Pct	Median	75th Pct	90th Pct
Errors	13.2	−25.6	−5.6	5.9	23.7	49.3
Cost estimate	9.3	−23.4	−8.7	3.1	23.4	46.5
Schedule estimate	0.4	0.0	0.0	0.0	0.0	1.2
Technical issues	3.6	0.0	0.0	0.0	1.3	8.5
Decisions	41.4	−13.7	−2.0	26.8	65.6	103.2
Requirements	15.9	−0.1	2.5	8.0	16.3	36.7
Affordability	−0.5	−2.6	−0.8	0.0	0.0	2.6
Quantity	18.9	−28.1	−9.2	14.5	34.1	74.9
Schedule changes	6.9	−0.3	0.3	3.2	7.2	19.1
Inter- or intraprogram transfers	0.3	−1.6	0.0	0.0	0.9	4.3
Financial	1.6	−0.3	−0.1	1.2	2.1	4.6
Exchange rate	0.2	0.0	0.0	0.0	0.0	0.0
Inflation	1.3	−0.3	−0.1	0.8	1.6	4.0
Miscellaneous	−0.9	−2.2	−0.5	0.0	0.0	0.1
Error correction	−0.7	−1.3	0.0	0.0	0.0	0.0
Unidentified	−0.2	−0.1	0.0	0.0	0.0	0.0
External events	0.0	0.0	0.0	0.0	0.0	0.0
Total	55.3	−8.2	6.7	28.8	55.5	131.0

Total Cost Growth, by Type of Program

Tables 3.11 through 3.13 show the causes and magnitude of cost growth across three types of programs: aircraft and helicopters, missiles, and electronics. As discussed earlier and shown in Tables 2.1 through 2.4, our sample of 35 programs included 10 aircraft and helicopter programs, six missile programs, 13 electronics programs, two launch-vehicle programs, two ground-vehicle programs, one satellite program, and one munitions program.

The growth in development, procurement, and total program cost for the first three program types is shown in the tables. Because the other program types consisted of so few programs, comparisons would

Table 3.11
Development Cost Growth, by Program Type (mean percentage)

Category	Aircraft and Helicopters (10)	Missiles (6)	Electronics (13)
Errors	23.6	19.5	16.8
Cost estimate	23.2	15.2	15.9
Schedule estimate	0.2	2.9	1.0
Technical issues	0.2	1.3	−0.1
Decisions	21.7	21.0	30.1
Requirements	15.5	17.5	13.2
Affordability	−4.5	−3.1	2.4
Quantity	−0.4	−0.8	6.2
Schedule changes	7.0	4.6	5.3
Inter- or intraprogram transfers	4.1	2.7	2.9
Financial	0.3	−0.2	2.1
Exchange rate	0.3	0.0	0.0
Inflation	0.0	−0.2	2.1
Miscellaneous	0.0	0.4	−2.3
Error correction	0.0	0.0	−1.3
Unidentified	0.0	0.4	−0.9
External events	0.0	0.0	0.0
Total	45.6	40.6	46.7

have been more representative of the individual program or two in the category than of the category as a whole.

There are some interesting differences in development cost growth among the program types, as shown in Table 3.11. Aircraft and helicopter programs appear to have higher development growth due to errors, mainly cost-estimating errors. Electronics programs seem to have an increase in quantity-related cost growth, whereas the other two types have a decrease. Electronics programs show a positive development growth for affordability, suggesting that initially unfunded requirements are subsequently funded. Of all the differences, only that of affordability development cost growth for electronics is statistically meaningful.

Table 3.12 shows procurement cost growth by system type. Aircraft and helicopter programs tend to have greater procurement cost

growth due to errors than the other program types. This difference is mainly driven by the higher growth in the cost-estimating category, but technical issues contribute as well. The differences in both errors in total and cost-estimating errors specifically are statistically significant. Note that electronics programs have negative procurement cost growth resulting from estimating errors.

Procurement cost growth due to decisions in aggregate is remarkably similar between types, but there are strong differences at the subcategory level. All electronics-program procurement cost growth is dominated by increases in quantity. However, this average is strongly driven by one program with very high quantity growth, the Global Broadcast System, which had a more than 400 percent increase in quantity. The differences in the quantity subcategory and decisions in aggregate are not statistically significant, due to the large variability in

Table 3.12
Procurement Cost Growth, by Program Type (mean percentage)

Category	Aircraft and Helicopters (10)	Missiles (6)	Electronics (13)
Errors	37.0	12.4	−0.4
Cost estimate	25.5	13.9	−5.9
Schedule estimate	0.1	0.1	1.6
Technical issues	11.4	−1.6	3.8
Decisions	47.3	46.4	48.8
Requirements	19.3	13.1	−1.6
Affordability	−0.7	3.1	−1.3
Quantity	13.5	15.4	49.8
Schedule changes	13.3	15.5	7.2
Inter- or intraprogram transfers	2.0	−0.8	−5.3
Financial	2.4	1.6	1.4
Exchange rate	0.5	0.0	0.0
Inflation	1.9	1.6	1.4
Miscellaneous	−0.2	−1.8	−0.7
Error correction	−0.2	0.0	−0.7
Unidentified	0.0	−1.8	0.0
External events	0.0	0.0	0.0
Total	86.4	58.5	49.1

the growth numbers. At the overall procurement cost growth level, the differences are not statistically significant either, despite the aircraft category having a much higher overall average. Within a particular type, procurement growth due to cost-estimating errors is the primary cause for aircraft; quantity dominates for electronics programs; and quantity and schedule both contribute to missile-program cost growth. Overall, decisions make a larger contribution to procurement growth than do errors.

The total cost growth by weapon-system type is shown in Table 3.13. The growth pattern largely follows that of procurement cost growth, described above, which makes sense, since procurement accounts for about three-quarters of the aggregate funding of development plus procurement. Aircraft and helicopter programs have higher total cost growth due to errors than do the other system types in the

Table 3.13
Total Cost Growth, by Program Type (mean percentage)

Category	Aircraft and Helicopters (10)	Missiles (6)	Electronics (13)
Errors	33.7	14.1	1.0
Cost estimate	26.7	14.7	−2.8
Schedule estimate	0.1	0.6	1.4
Technical issues	7.0	−1.1	2.4
Decisions	38.4	29.6	26.4
Requirements	19.0	12.6	6.6
Affordability	−2.5	0.0	−0.5
Quantity	8.4	3.3	17.6
Schedule changes	11.6	13.5	5.9
Inter- or intraprogram transfers	2.0	0.2	−3.2
Financial	1.6	0.8	1.5
Exchange rate	0.4	0.0	0.0
Inflation	1.1	0.8	1.5
Miscellaneous	−0.2	−0.7	−1.5
Error correction	−0.2	0.0	−0.8
Unidentified	0.0	−0.7	−0.6
External events	0.0	0.0	0.0
Total	73.5	43.9	27.5

sample. Again, this is driven by errors in cost estimating. Within each program type, decisions make a larger contribution than do errors. Electronics programs would show just 10 percent total cost growth if it were not for quantity changes, while the total cost growth in aircraft and missile programs would be only slightly decreased if quantity changes were excluded.

Summary and Recommendations

In this study, we examined 35 mature acquisition programs—16 Air Force programs and 19 non–Air Force programs—to identify the sources of cost growth. We found no statistically significant differences in the causes of cost growth between the two subsets of programs.

Because the approach we used is different from that used in prior studies, it is difficult to compare the results. In order to allocate all the variance data provided in the SAR for each program, we did not normalize our results for changes in quantity, as was done in most prior studies. In addition, we chose mature programs that were far enough along in the weapon-system acquisition process that most of their cost growth had already occurred, whereas most prior studies have included any program that was at least three years past its MS B.

Programs begun since March 2001 are not included in this analysis. Their cost growth and its causes may be different from those of programs analyzed here. Trends suggesting that newer programs may exhibit different cost-growth behavior include the growing fraction of total program cost in development and the ever-increasing complexity and software-intensity of major defense acquisition programs.

Cost-Allocation Challenges

Comparing causes of cost growth in different programs requires some caution. This is not an exact science, and even if the information is presented fully and correctly, allocating it to a specific category can be difficult. When a contractor cannot meet the requirements of the pro-

gram with the resources available within the program schedule, allocating the resulting cost variances to a specific cause is complex and challenging.

In some programs, technical problems delay development and lead to higher costs and the failure to meet a planned schedule. A more complex situation arises when a technical issue within a program causes development to fall behind schedule. In this case, the program office may have to replan the development program and change the schedule, and the contractor and Air Force may decide to change the system design to incorporate a different technical solution. This solution takes longer to implement, which also delays the program and extends the schedule. Here, a technical issue results in cost growth that could be associated with several categories, because the decisions made did not necessarily have to be made, and they had implications for most aspects of the program.

It is clear that even under the best of circumstances, identifying causes of cost growth will remain an inexact science, requiring that some after-the-fact variance allocations be best guesses based on the available (and sometimes very limited) information and on trained judgment. Moreover, in some instances, the contextual information provided in SARs and the descriptions of variances are not sufficiently detailed to ascertain the underlying causes with certainty. As a result, in this study it was not always possible to conclusively identify the source of a cost variance or to determine precisely where it fell in our scheme of categories. Also, because each SAR is a snapshot in time, and later developments help put program progress into perspective, a focused analysis after the fact may provide a better categorization of costs than is possible at the time the SAR is prepared.

Results of This Analysis

Program Sample
In our sample of 35 mature programs, development cost growth is driven equally by cost-estimating errors and requirements growth, which account for almost two-thirds of the total. Lesser contributors

to development cost growth are decisions to change schedule, miscel-laneous variances, program transfers, and quantity changes.

Procurement cost growth is driven by quantity changes (usu-ally increases in quantity), which account for more than half the total growth. Decisions to change the schedule, additional requirements, and cost-estimating errors account for almost all of the remaining pro-curement cost growth.

At the total program level (development plus procurement), more than one-third of the cost increases were due to decisions to change quantity. Each of three of our cost categories accounted for about one-sixth of the total: decisions to add requirements, cost-estimating errors, and decisions to change schedule. All other categories are minor con-tributors. Overall, more than two-thirds of the cost growth is attribut-able to decisions.

Program Type

We found only three program types that had sufficient sample sizes to allow meaningful comparisons: aircraft and helicopters, missiles, and electronics. All showed remarkably similar sources of cost growth in development. In procurement, aircraft and helicopters showed the greatest total cost growth, followed by missiles, and then electron-ics. In aircraft and helicopter programs, cost-estimating errors were the largest contributor to procurement cost growth, with decisions on requirements contributing substantially as well. Lesser contributors were decisions on quantity and schedule and technical issues. Mis-sile cost growth was split four ways, roughly equally, among decisions on schedule, quantity, and requirements, and cost-estimating errors. Quantity accounted for all the growth in the electronics programs, with the other categories offsetting each other with small percentages of positive and negative cost growth.

Growth in Air Force Programs

The cost-growth results for the programs managed by the Air Force are similar to those for the full program sample. The mean values are slightly higher for Air Force programs, but the differences are not sta-tistically significant.

Despite the statistical insignificance of the differences between Air Force and non–Air Force programs, interesting relative cost-growth differences are worthy of note. Development cost growth is higher in Air Force programs: 60 percent, compared with 53 percent. However, the exclusion of a single miscellaneous event in a single Air Force program (Titan IV) would reduce the average cost growth to 47 percent.

Procurement cost growth is much higher in the Air Force programs: 95 percent, compared with 59 percent. This 36 percent difference is accounted for by differences in two subcategories: Cost-estimating errors account for about one-third of the difference, decisions on quantity for the remaining two-thirds.

High standard deviations and relatively small sample sizes explain why the observed differences, which may appear significant to the casual observer, are not so when basic statistical tests are applied.

Ways to Improve SAR Data

Our attribution of cost variances in the SARs to underlying causes was challenging because of the inconsistent quality and nonspecific attribution in many SAR cost-variance descriptions. To improve understanding of the causes of cost growth in programs, more stringent specifications and consistent application of the variance descriptions should be considered. This could greatly enhance the usefulness of the SARs to their customers. An updated set of variances that are more causally oriented should also be considered by SAR authorities in OSD.

Two minor changes that could easily be made to the current SAR variance categories would also greatly improve the usefulness of SAR cost-variance data:

- Each variance value should be restricted to a single explanation. Current practice on many programs is to string together two to five seemingly unrelated causes and associate a single cost-variance value to the aggregate. This practice makes it impossible to understand the relative contribution of each of the contributors to the total variance value.
- Larger cost variances should be accompanied by more meaningful explanations. A detailed narrative describing events and activi-

ties leading up to the ultimate recognition of the variance should be required for those with values over a specified threshold (e.g., $10 million in FY 2005 dollars). This additional explanation would not place too much additional demand on SAR preparers, because the vast majority of the variances reported are small. Rarely are there more than eight variances in any one SAR of sufficient value to precipitate the invocation of this added requirement.

On a more general note, given the attention paid by Congress and OSD to the SARs, the Air Force (as well as the other services) should redouble its efforts to ensure that the information in these reports is accurate and complete before the reports are transmitted to higher authority. The more explicit the program office is in explaining cost growth, the more transparent the reasons for cost growth will be to all higher authorities.

Where Should Air Force Decisionmakers Direct Their Focus?

Cost growth due to errors indicates that the original baseline underestimates the cost, schedule, and technical difficulties required to get the job done. Reductions in these errors, without changes in specified capability, mean that baseline estimates will be higher and the resources ultimately required to get the job done will not substantially decrease. The result is that little in the way of budget outlays will ultimately be saved. Conversely, cost growth due to decisions changes the acquisition plan from that which was in effect at MS B and in most cases results in requiring substantially more resources to complete the system acquisition. This translates to real growth in required budget outlays over time.

Consequently, reducing cost growth due to errors provides for more executable baseline plans and less program-execution churn, but it does not free up substantial additional resources. Reducing cost growth due to decisions provides for less flexibility as acquisition pro-

grams unfold but will consume fewer additional resources in the long run, thus freeing up resources for other acquisition priorities.

Decisionmakers should balance their efforts to reduce cost growth between errors-related and decision-related causes, keeping in mind the differing effects of reducing each.

Our results show that the majority of growth is caused by decisions—the choices made throughout the course of an acquisition program. Changes in requirements and in quantity and production schedule are the dominant causes of cost growth. Any effort to reduce cost growth should look to ways to contain changes in these areas. Of course, we understand that a careful balance must be struck between containing growth and providing the right capabilities to the warfighter.

Errors also account for a substantial portion of cost growth. There is clearly a need to improve the quality and accuracy of cost estimates, particularly in the areas that show the largest cost growth: development cost estimates and overall aircraft cost estimates. Cost-estimating errors have traditionally been attributed to the cost analysts, but the problem is deeper than this. The analysts base their estimates on the technical characteristics provided them by the engineers, technology experts, and other program-management professionals. Better analyses and forecasts by all of these groups would provide a foundation for improving the quality of cost estimates.

Future Research

This analysis has focused on the relative contributions to cost growth from various sources through averages and distributions associated with a group of programs. In Appendix B we briefly explore weighted average cost growth and find markedly different results. These differences suggest that strategies to control cost growth at the individual program level may not provide commensurate cost-growth relief for the weapon-system portfolio as a whole. If this is the case, the continuing unacceptable level of cost growth at the portfolio level may not ebb, even if growth is more controlled at the individual-program level. That, in turn, will ensure that the cycle of budgetary shortfalls that

precipitates funding cuts at the individual-program level, which in turn causes program replans that precipitate schedule slips and cost growth, is not mitigated. To better understand how to avoid this outcome, an in-depth analysis of the differences in cost-growth causes for programs of various sizes would provide insights into the relative importance of various management strategies for each program.

Cost Growth of Individual Programs

This appendix presents tables of cost growth for individual programs. To prepare these tables, we identified the growth in development and procurement costs in each program and assigned the cost variances to the RAND categories.[1]

Values in all the tables represent cumulative cost growth from MS B through the last program SAR or the December 2005 SAR (for programs that are still active). All costs were converted to base-year 2005 dollars, using the FY 2006 raw inflation indices dated January 19, 2006.

Table A.1 shows development cost growth, and Table A.2 shows procurement cost growth. Total costs for each appropriation are shown, along with the program name, date of final estimate, percentage complete (by value), program type, lead military service, baseline cost estimate, final cost estimate, and cost growth by contributors in each category.

To show the relative importance of the various cost-growth contributors in each program, we calculated the percentage growth from the program baseline cost estimate (by appropriation) associated with each cost category. These results are shown in Tables A.3 and A.4. Table A.3 gives the percentage growth in development costs, and Table A.4 gives the percentage growth in procurement costs.

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[1] We originally included military construction costs in our analysis, but we found that they were small and rarely relevant to a program, so we did not include them in the final results.

Table A.1
Development Cost Growth by Category for 35 Mature Programs (millions of base year 2005 dollars)

Category	AFATDS	AMRAAM	ATACMS	B-IB	B-IB CMUP Computer	B-IB CMUP JDAM	BFVSA3	C-17	CBU-97B
SAR date of final estimate	Dec 98	Dec 05	Dec 99	Dec 92	Dec 04	Dec 99	Dec 05	Dec 05	Dec 98
Development completed (by value)	74.2%	91.9%	100.0%	85.7%	100.0%	99.8%	100.0%	90.5%	94.6%
Service	Army	AF	Army	AF	AF	AF	Army	AF	AF
Type of system	Electronic	Missile	Missile	Aircraft/ Helo	Electronic	Electronic	Vehicle	Aircraft/ Helo	Munition
Final development cost estimate	772.4	2,891.6	937.4	6,446.5	259.0	361.1	571.4	9,855.0	391.1
Baseline development cost estimate	520.9	1,871.2	969.5	4,904.1	271.1	471.9	467.8	5,562.6	193.7
Development cost growth	251.5	1,020.4	−32.1	1,542.4	−12.1	−110.8	103.6	4,292.3	197.4
Errors	125.7	199.3	−1.8	839.5	−14.0	−53.2	−2.7	1,698.3	125.3
Cost estimate	109.2	78.3	−1.8	836.0	−41.1	−53.2	−14.3	1,612.5	125.3
Schedule estimate	16.5	0.0	0.0	0.0	27.1	0.0	11.6	85.8	0.0
Technical issues	0.0	121.0	0.0	3.5	0.0	0.0	0.0	0.0	0.0
Decisions	131.0	792.0	−29.7	657.5	−1.5	0.0	94.6	2,731.1	71.4
Requirements	89.7	752.6	111.4	878.9	−1.5	0.0	98.2	889.0	70.7
Affordability	0.0	−22.7	−141.1	−487.9	0.0	0.0	0.0	221.1	−9.2
Quantity	0.0	−78.7	0.0	0.0	0.0	0.0	−3.6	0.0	8.5
Schedule changes	41.3	34.2	0.0	0.0	0.0	0.0	0.0	686.8	0.0
Inter- or intraprogram transfers	0.0	106.6	0.0	266.6	0.0	0.0	0.0	934.2	1.4
Financial	−5.2	29.0	−0.6	45.4	3.4	−0.8	14.6	−137.1	0.7
Exchange rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inflation	−5.2	29.0	−0.6	45.4	3.4	−0.8	14.6	−137.1	0.7
Miscellaneous	0.0	0.0	0.0	0.0	0.0	−56.8	−2.8	0.0	0.0
Error correction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified	0.0	0.0	0.0	0.0	0.0	−56.8	−2.8	0.0	0.0
External events	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Category	E-6A	F/A-18E/F	F-22	GBS	JAVELIN	JDAM	JPATS	JSOW	JSTARS
SAR date of final estimate	Dec 91	Dec 05	Dec 05	Dec 05	Dec 05	Dec 05	Dec 05	Dec 05	Dec 03
Percentage complete (by value)	100.0%	100.0%	93.2%	86.1%	100.0%	97.8%	96.3%	100.0%	90.0%
Service	Navy	Navy	AF	AF	Army	AF	AF	Navy	AF
Type of system	Aircraft/ Helo	Aircraft/ Helo	Aircraft/ Helo	Electronic	Missile	Electronic	Aircraft/ Helo	Electronic	Aircraft/ Helo
Final development cost estimate	580.7	6,450.6	32,650.3	463.2	979.0	661.8	318.4	1,372.2	4,762.9
Baseline development cost estimate	517.6	6,569.3	22,078.0	444.6	732.2	566.4	366.6	919.9	2,003.8
Development cost growth	63.1	−118.7	10,572.4	18.6	246.8	95.4	−48.2	452.3	2,759.1
Errors	48.6	−177.4	3,694.5	33.9	246.0	−31.1	−50.6	82.3	1,747.2
Cost estimate	44.2	−177.4	3,694.5	33.9	107.0	−31.1	−50.6	85.0	1,747.2
Schedule estimate	0.0	0.0	0.0	0.0	129.5	0.0	0.0	0.0	0.0
Technical issues	4.4	0.0	0.0	0.0	9.5	0.0	0.0	−2.7	0.0
Decisions	14.5	2.4	6,372.9	−18.5	0.0	123.7	−6.3	360.1	1,028.8
Requirements	0.0	0.0	703.8	30.5	0.0	2.4	9.0	318.8	940.9
Affordability	0.0	12.4	−255.3	−26.3	0.0	121.7	0.0	41.3	−650.9
Quantity	14.5	0.0	−1,510.5	0.0	0.0	−0.3	0.0	0.0	0.0
Schedule changes	0.0	0.0	4,635.8	0.0	0.0	0.0	0.0	0.0	757.7
Inter- or intraprogram transfers	0.0	−10.0	2,799.0	−22.7	0.0	0.0	−15.3	0.0	−18.9
Financial	0.0	56.3	507.8	3.1	0.8	2.8	8.7	−7.9	−17.0
Exchange rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inflation	0.0	56.3	507.8	3.1	0.8	2.8	8.7	−7.9	−17.0
Miscellaneous	0.0	0.0	−2.8	0.0	0.0	0.0	0.0	17.8	0.0
Error correction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.8	0.0
Unidentified	0.0	0.0	−2.8	0.0	0.0	0.0	0.0	0.0	0.0
External events	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table A.1 (continued)

Category	JSTARS CGS	Longbow Apache AF	Longbow Apache FCR	Longbow Hellfire	MCS	MIDS LVT	MM GRP	MM PRP	OH-58D
SAR date of final estimate	Dec 01	Dec 05	Dec 03	Dec 04	Dec 04	Dec 05	Dec 05	Dec 05	Jun 95
Percentage complete (by value)	88.4%	100.0%	100.0%	100.0%	88.8%	76.1%	100.0%	100.0%	99.5%
Service	Army	Army	Army	Army	Army	Navy	AF	AF	Army
Type of system	Electronic	Aircraft/ Helo	Electronic	Missile	Electronic	Electronic	Electronic	LS	Aircraft/ Helo
Final development cost estimate	843.5	847.9	963.0	497.2	398.8	1,245.8	617.4	375.6	429.1
Baseline development cost estimate	374.3	427.2	985.9	387.8	146.8	598.2	512.5	403.6	379.4
Development cost growth	469.2	420.7	−22.9	109.4	252.0	647.5	104.9	−28.0	49.7
Errors	111.6	242.6	4.5	58.1	150.4	−7.5	38.7	−5.0	−15.2
Cost estimate	111.6	239.4	4.5	58.1	150.4	−7.5	38.7	−5.0	−15.2
Schedule estimate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical issues	0.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Decisions	346.9	188.3	−4.5	54.3	92.1	646.8	67.2	−28.1	63.9
Requirements	153.8	206.3	0.0	54.3	0.0	382.8	−71.7	0.0	72.7
Affordability	0.0	−18.0	−4.5	0.0	0.0	49.9	25.7	−28.1	−3.9
Quantity	234.1	0.0	0.0	0.0	0.0	110.1	0.0	0.0	0.0
Schedule changes	6.6	0.0	0.0	0.0	20.7	68.6	121.4	0.0	−5.0
Inter- or intraprogram transfers	−47.6	0.0	0.0	0.0	71.5	35.3	−8.2	0.0	0.0
Financial	10.7	−10.2	−19.1	−2.9	9.5	8.2	−1.1	5.1	1.1
Exchange rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inflation	10.7	−10.2	−19.1	−2.9	9.5	8.2	−1.1	5.1	1.1
Miscellaneous	0.0	0.0	−3.8	0.0	0.0	0.0	0.0	0.0	0.0
Error correction	0.0	0.0	−3.8	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
External events	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table A.1 (continued)

Category	Patriot PAC3	AWACS RSIP	SMART-T	Stryker	T45TS	Titan IV	Trident II Missile	WGS
SAR date of final estimate	Dec 05	Dec 03	Dec 99	Dec 05	Dec 05	Dec 01	Dec 05	Dec 05
Percentage complete (by value)	96.4%	100.0%	84.7%	87.7%	100.0%	99.4%	99.1%	63.8%
Service	Army	AF	Army	Army	Navy	AF	Navy	AF
Type of system	Missile	Electronic	Electronic	Vehicle	Aircraft/Helo	LS	Missile	SAT
Final development cost estimate	2,904.2	520.5	367.5	729.2	1,219.0	4,978.6	14,394.4	317.6
Baseline development cost estimate	1,223.4	484.9	197.2	530.3	798.3	910.8	15,421.3	187.7
Development cost growth	1,680.8	35.6	170.3	198.9	396.2	4,067.9	−1,026.9	129.9
Errors	797.5	63.1	94.3	183.8	306.6	245.7	−1,124.0	−17.3
Cost estimate	797.5	65.8	94.3	128.8	306.6	227.2	−1,124.0	−17.3
Schedule estimate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical issues	0.0	−2.8	0.0	55.0	0.0	18.5	0.0	0.0
Decisions	886.2	−33.6	80.3	10.9	98.5	1,915.2	67.1	147.3
Requirements	471.3	5.5	42.2	−25.0	7.1	841.2	136.2	63.7
Affordability	−32.4	−5.8	0.0	0.0	0.0	−109.2	−1.7	−19.3
Quantity	0.0	0.0	0.0	35.9	0.0	89.9	−67.4	107.3
Schedule changes	315.8	47.3	0.0	0.0	0.0	410.7	0.0	0.0
Inter- or intraprogram transfers	131.5	−80.6	38.2	0.0	91.5	682.6	0.0	−4.4
Financial	−30.4	6.1	33.2	4.2	15.6	7.9	30.0	−0.1
Exchange rate	0.0	0.0	0.0	0.0	24.5	0.0	0.0	0.0
Inflation	−30.4	6.1	33.2	4.2	−8.9	7.9	30.0	−0.1
Miscellaneous	27.6	0.0	−37.5	0.0	0.0	1,899.1	0.0	0.0
Error correction	0.0	0.0	−37.5	0.0	0.0	0.0	0.0	0.0
Unidentified	27.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
External events	0.0	0.0	0.0	0.0	0.0	1,899.1	0.0	0.0

Table A.2
Procurement Cost Growth by Category for 35 Mature Programs
(millions of base year 2005 dollars)

Category	AFATDS	AMRAAM	ATACMS	B-IB	B-IB CMUP Computer	B-IB CMUP JDAM	BFVSA3	C-17	CBU 97B
SAR date of final estimate	Dec 98	Dec 05	Dec 99	Dec 92	Dec 04	Dec 99	Dec 05	Dec 05	Dec 98
Procurement complete (by value)	39.6%	77.7%	93.3%	98.0%	97.9%	70.8%	49.2%	87.6%	52.3%
Service	Army	AF	Army	AF	AF	AF	Army	AF	AF
Type of system	Electronic	Missile	Missile	Aircraft/ Helo	Electronic	Electronic	Vehicle	Aircraft/ Helo	Munition
Final procurement cost estimate	745.4	12,163.6	1,822.4	36,924.7	107.9	235.0	7,767.3	52,698.9	1,616.2
Baseline procurement cost estimate	771.7	11,275.2	720.8	37,645.7	179.0	231.8	3,208.7	34,969.4	2,612.5
Procurement cost growth	−26.3	888.3	1,101.6	−721.0	−71.1	3.2	4,558.6	17,729.6	−996.3
Errors	−244.1	2,346.3	−52.8	762.3	−41.1	−1.0	1,027.9	6,257.4	−85.6
Cost estimate	−257.4	1,959.7	−52.8	762.3	−31.4	−1.0	1,014.4	6,446.2	−314.9
Schedule estimate	13.3	0.0	0.0	0.0	−4.0	0.0	0.0	−188.8	229.3
Technical issues	0.0	386.6	0.0	0.0	−5.8	0.0	13.5	0.0	0.0
Decisions	215.1	−1,486.8	1,188.1	−2,151.9	−30.1	9.9	3,518.9	11,178.9	−936.4
Requirements	−27.2	527.7	182.3	324.7	0.0	0.0	451.9	1,809.3	87.5
Affordability	0.0	136.4	103.3	−2,205.6	0.0	0.0	0.0	−860.9	0.0
Quantity	242.3	−4,277.3	874.5	0.0	−30.1	−1.2	2,655.4	5,893.7	−1,154.3
Schedule changes	0.0	2,170.6	19.4	0.0	0.0	11.1	308.1	7,479.4	149.6
Inter- or intraprogram transfers	0.0	−44.2	8.6	−271.0	0.0	0.0	103.5	−3,142.7	−19.2
Financial	2.7	28.8	45.2	668.6	0.2	−5.7	31.2	293.3	25.6
Exchange rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inflation	2.7	28.8	45.2	668.6	0.2	−5.7	31.2	293.3	25.6
Miscellaneous	0.0	0.0	−78.9	0.0	0.0	0.0	−19.5	0.0	0.0
Error correction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified	0.0	0.0	−78.9	0.0	0.0	0.0	−19.5	0.0	0.0
External events	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table A.2 (continued)

Category	E-6A	F/A-18E/F	F-22	GBS	JAVELIN	JDAM	JPATS	JSOW	JSTARS
SAR date of final estimate	Dec 91	Dec 05	Dec 05	Dec 05	Dec 05	Dec 05	Dec 05	Dec 05	Dec 03
Percentage complete (by value)	99.8%	70.7%	60.6%	61.6%	92.7%	76.3%	41.5%	87.4%	96.3%
Service	Navy	Navy	AF	AF	Army	AF	AF	Navy	AF
Type of system	Aircraft/ Helo	Aircraft/ Helo	Aircraft/ Helo	Electronic	Missile	Electronic	Aircraft/ Helo	Electronic	Aircraft/ Helo
Final procurement cost estimate	2,366.0	38,903.8	32,884.9	297.5	3,854.8	4,477.7	4,820.4	3,874.9	6,104.5
Baseline procurement cost estimate	2,471.0	65,429.1	58,008.0	60.3	3,799.1	2,415.2	2,913.3	7,288.9	1,817.3
Procurement cost growth	−105.0	−26,525.3	−25,123.2	237.2	55.7	2,062.5	1,907.0	−3,414.0	4,287.3
Errors	125.5	−312.5	410.8	31.1	1,793.4	166.1	752.2	−3,295.8	1,951.1
Cost estimate	125.5	−312.5	410.8	31.1	1,770.4	25.1	752.2	−3,489.1	909.0
Schedule estimate	0.0	0.0	0.0	0.0	23.1	141.1	0.0	0.0	0.0
Technical issues	0.0	0.0	0.0	0.0	0.0	0.0	0.0	193.2	1,042.2
Decisions	−245.9	−27,291.1	−25,633.4	206.4	−1,774.4	1,912.5	1,167.6	−120.7	2,137.1
Requirements	−189.9	295.2	473.0	−34.7	152.8	−58.7	212.6	340.1	404.4
Affordability	−124.5	3.1	−90.1	−0.4	−0.4	0.0	11.0	−89.6	−63.5
Quantity	78.6	−24,089.5	−36,917.4	241.5	−1,834.6	1,910.8	373.9	−371.2	713.5
Schedule changes	−10.1	148.2	13,430.4	0.0	−104.2	91.0	570.1	0.0	1,068.3
Inter- or intraprogram transfers	0.0	−3,648.0	−2,529.2	0.0	16.0	−30.7	0.0	0.0	14.5
Financial	15.5	1,078.3	86.5	−0.2	36.7	−16.1	−12.8	2.5	199.0
Exchange rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inflation	15.5	1,078.3	86.5	−0.2	36.7	−16.1	−12.8	2.5	199.0
Miscellaneous	0.0	0.0	12.9	0.0	0.0	0.0	0.0	0.0	0.0
Error correction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified	0.0	0.0	12.9	0.0	0.0	0.0	0.0	0.0	0.0
External events	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table A.2 (continued)

Category	JSTARS CGS	Longbow Apache AF	Longbow Apache FCR	Longbow Hellfire	MCS	MIDS LVT	MM GRP	MM PRP	OH-58D
SAR date of final estimate	Dec 01	Dec 05	Dec 03	Dec 04	Dec 04	Dec 05	Dec 05	Dec 05	Jun 95
Percentage complete (by value)	93.1%	74.3%	97.9%	99.2%	74.4%	70.7%	81.4%	65.6%	97.4%
Service	Army	Army	Army	Army	Army	Navy	AF	AF	Army
Type of system	Electronic	Aircraft/ Helo	Electronic	Missile	Electronic	Electronic	Electronic	LS	Aircraft/ Helo
Final procurement cost estimate	794.5	8,081.8	906.7	2,185.0	232.4	982.1	1,940.7	2,209.7	3,749.2
Baseline procurement cost estimate	734.6	1,290.9	652.9	1,718.9	343.2	509.7	1,259.5	2,268.8	2,781.3
Procurement cost growth	59.9	6,790.9	253.8	466.2	–110.8	472.4	681.2	–59.1	967.8
Errors	–53.4	1,875.0	241.2	–832.7	–176.0	–244.9	277.9	–82.9	640.3
Cost estimate	–328.5	1,139.8	169.2	–607.5	–175.9	–244.9	259.2	–75.6	640.3
Schedule estimate	0.0	0.0	0.0	0.0	–0.1	0.0	0.0	–7.2	0.0
Technical issues	275.2	735.2	72.0	–225.2	0.0	0.0	18.6	0.0	0.0
Decisions	86.8	4,929.8	1.7	1,267.3	55.7	711.5	395.2	–47.8	277.3
Requirements	403.5	1,632.4	65.6	24.3	–6.7	–273.7	–53.6	0.0	984.7
Affordability	–146.2	146.9	–12.0	0.0	0.0	0.0	88.0	–16.0	49.5
Quantity	141.6	2,656.0	–136.2	306.0	82.7	843.0	9.2	–13.4	852.7
Schedule changes	29.3	–6.1	84.3	937.0	0.0	164.1	340.6	–18.4	195.1
Inter- or intraprogram transfers	–341.4	500.6	0.0	0.0	–20.3	–22.0	11.0	0.0	0.2
Financial	40.0	13.0	14.1	31.6	9.5	5.8	8.1	17.2	50.3
Exchange rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inflation	40.0	13.0	14.1	31.6	9.5	5.8	8.1	17.2	50.3
Miscellaneous	–13.5	–27.0	–3.2	0.0	0.0	0.0	0.0	54.4	0.0
Error correction	–13.5	–27.0	–3.2	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
External events	0.0	0.0	0.0	0.0	0.0	0.0	0.0	54.4	0.0

Table A.2 (continued)

Category	Patriot PAC3	AWACS RSIP	SMART-T	Stryker	T45TS	Titan IV	Trident II Missile	WGS
SAR date of final estimate	Dec 05	Dec 03	Dec 99	Dec 05	Dec 05	Dec 01	Dec 05	Dec 05
Percentage complete (by value)	75.9%	95.3%	44.1%	55.0%	90.5%	100.0%	70.0%	42.7%
Service	Army	AF	Army	Army	Navy	AF	Navy	AF
Type of system	Missile	Electronic	Electronic	Vehicle	Aircraft/ Helo	LS	Missile	SAT
Final procurement cost estimate	6,531.1	619.2	647.4	8,671.3	6,542.1	16,211.3	30,097.9	1,604.2
Baseline procurement cost estimate	2,583.0	308.0	754.4	6,200.9	4,621.9	2,467.9	27,659.2	858.9
Procurement cost growth	3,948.1	311.2	−106.9	2,470.4	1,701.7	13,743.4	2,438.7	745.2
Errors	1,734.7	232.0	64.4	305.9	1,991.3	653.3	−1,430.1	173.3
Cost estimate	1,734.7	183.1	64.4	80.6	1,939.0	309.8	−1,430.1	19.2
Schedule estimate	0.0	48.8	0.0	0.0	52.3	0.0	0.0	0.0
Technical issues	0.0	0.0	0.0	225.3	0.0	343.4	0.0	154.0
Decisions	2,194.1	63.8	−151.9	2,178.1	−310.9	11,134.9	4,035.4	566.1
Requirements	511.6	83.5	48.4	35.3	82.9	1,507.6	6,490.8	23.6
Affordability	112.4	0.0	−3.4	0.0	0.0	−166.1	−274.6	−27.1
Quantity	1,305.8	−26.6	−155.6	1,292.9	−546.0	10,202.5	−3,088.9	703.6
Schedule changes	395.3	24.6	3.7	849.9	152.2	0.0	1,110.4	11.8
Inter- or intraprogram transfers	−130.9	−17.7	−45.1	0.0	0.0	−409.1	−202.3	−145.8
Financial	20.3	15.4	33.2	−21.3	239.8	201.3	−166.7	5.9
Exchange rate	0.0	0.0	0.0	0.0	218.5	0.0	0.0	0.0
Inflation	20.3	15.4	33.2	−21.3	21.3	201.3	−166.7	5.9
Miscellaneous	−1.0	0.0	−52.6	7.7	0.0	1,754.0	0.0	0.0
Error correction	0.0	0.0	−52.6	0.0	0.0	0.0	0.0	0.0
Unidentified	−1.0	0.0	0.0	7.7	0.0	0.0	0.0	0.0
External events	0.0	0.0	0.0	0.0	0.0	1,754.0	0.0	0.0

Table A.3
Percentage Growth in Development Cost for 35 Mature Programs

Category	AFATDS	AMRAAM	ATACMS	B-IB	B-IB CMUP Computer	B-IB CMUP JDAM	BFVSA3	C-17	CBU 97B
SAR date of final estimate	Dec 98	Dec 05	Dec 99	Dec 92	Dec 04	Dec 99	Dec 05	Dec 05	Dec 98
Percentage complete (by value)	74.2	91.9	100.0	85.7	100.0	99.8	100.0	90.5	94.6
Service	Army	AF	Army	AF	AF	AF	Army	AF	AF
Type of system	Electronic	Missile	Missile	Aircraft/ Helo	Electronic	Electronic	Vehicle	Aircraft/ Helo	Munition
Baseline development cost estimate ($ millions)	520.9	1,871.2	969.5	4,904.1	271.1	471.9	467.8	5,562.6	193.7
Development cost growth ($ millions)	251.5	1,020.4	−32.1	1,542.4	−12.1	−110.8	103.6	4,292.3	197.4
Errors	24.1	10.7	−0.2	17.1	−5.2	−11.3	−0.6	30.5	64.7
Cost estimate	21.0	4.2	−0.2	17.0	−15.2	−11.3	−3.1	29.0	64.7
Schedule estimate	3.2	0.0	0.0	0.0	10.0	0.0	2.5	1.5	0.0
Technical issues	0.0	6.5	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Decisions	25.1	42.3	−3.1	13.4	−0.6	0.0	20.2	49.1	36.9
Requirements	17.2	40.2	11.5	17.9	−0.6	0.0	21.0	16.0	36.5
Affordability	0.0	−1.2	−14.6	−9.9	0.0	0.0	0.0	4.0	−4.8
Quantity	0.0	−4.2	0.0	0.0	0.0	0.0	−0.8	0.0	4.4
Schedule changes	7.9	1.8	0.0	0.0	0.0	0.0	0.0	12.3	0.0
Inter- or intraprogram transfers	0.0	5.7	0.0	5.4	0.0	0.0	0.0	16.8	0.7
Financial	−1.0	1.6	−0.1	0.9	1.2	−0.2	3.1	−2.5	0.4
Exchange rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inflation	−1.0	1.6	−0.1	0.9	1.2	−0.2	3.1	−2.5	0.4
Miscellaneous	0.0	0.0	0.0	0.0	0.0	−12.0	−0.6	0.0	0.0
Error correction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified	0.0	0.0	0.0	0.0	0.0	−12.0	−0.6	0.0	0.0
External events	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table A.3 (continued)

Category	E-6A	F/A-18E/F	F-22	GBS	JAVELIN	JDAM	JPATS	JSOW	JSTARS
SAR date of final estimate	Dec 91	Dec 05	Dec 05	Dec 05	Dec 05	Dec 05	Dec 05	Dec 05	Dec 03
Percentage complete (by value)	100.0	100.0	93.2	86.1	100.0	97.8	96.3	100.0	90.0
Service	Navy	Navy	AF	AF	Army	AF	AF	Navy	AF
Type of system	Aircraft/ Helo	Aircraft/ Helo	Aircraft/ Helo	Electronic	Missile	Electronic	Aircraft/ Helo	Electronic	Aircraft/ Helo
Baseline development cost estimate ($ millions)	517.6	6,569.3	22,078.0	444.6	732.2	566.4	366.6	919.9	2,003.8
Development cost growth ($ millions)	63.1	−118.7	10,572.4	18.6	246.8	95.4	−48.2	452.3	2,759.1
Errors	9.4	−2.7	16.7	7.6	33.6	−5.5	−13.8	8.9	87.2
Cost estimate	8.5	−2.7	16.7	7.6	14.6	−5.5	−13.8	9.2	87.2
Schedule estimate	0.0	0.0	0.0	0.0	17.7	0.0	0.0	0.0	0.0
Technical issues	0.9	0.0	0.0	0.0	1.3	0.0	0.0	−0.3	0.0
Decisions	2.8	0.0	28.9	−4.2	0.0	21.8	−1.7	39.1	51.3
Requirements	0.0	0.0	3.2	6.9	0.0	0.4	2.4	34.7	47.0
Affordability	0.0	0.2	−1.2	−5.9	0.0	21.5	0.0	4.5	−32.5
Quantity	2.8	0.0	−6.8	0.0	0.0	−0.1	0.0	0.0	0.0
Schedule changes	0.0	0.0	21.0	0.0	0.0	0.0	0.0	0.0	37.8
Inter- or intraprogram transfers	0.0	−0.2	12.7	−5.1	0.0	0.0	−4.2	0.0	−0.9
Financial	0.0	0.9	2.3	0.7	0.1	0.5	2.4	−0.9	−0.8
Exchange rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inflation	0.0	0.9	2.3	0.7	0.1	0.5	2.4	−0.9	−0.8
Miscellaneous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0
Error correction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0
Unidentified	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
External events	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table A.3 (continued)

Category	JSTARS CGS	Longbow Apache AF	Longbow Apache FCR	Longbow Hellfire	MCS	MIDS LVT	MM GRP	MM PRP	OH-58D
SAR date of final estimate	Dec 01	Dec 05	Dec 03	Dec 04	Dec 04	Dec 05	Dec 05	Dec 05	Jun 95
Percentage complete (by value)	88.4	100.0	100.0	100.0	88.8	76.1	100.0	100.0	99.5
Service	Army	Army	Army	Army	Army	Navy	AF	AF	Army
Type of system	Electronic	Aircraft/Helo	Electronic	Missile	Electronic	Electronic	Electronic	LS	Aircraft/Helo
Baseline development cost estimate ($ millions)	374.3	427.2	985.9	387.8	146.8	598.2	512.5	403.6	379.4
Development cost growth ($ millions)	469.2	420.7	−22.9	109.4	252.0	647.5	104.9	−28.0	49.7
Errors	29.8	56.8	0.5	15.0	102.5	−1.2	7.6	−1.2	−4.0
Cost estimate	29.8	56.0	0.5	15.0	102.5	−1.2	7.6	−1.2	−4.0
Schedule estimate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical issues	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Decisions	92.7	44.1	−0.5	14.0	62.8	108.1	13.1	−7.0	16.8
Requirements	41.1	48.3	0.0	14.0	0.0	64.0	−14.0	0.0	19.2
Affordability	0.0	−4.2	−0.5	0.0	0.0	8.3	5.0	−7.0	−1.0
Quantity	62.5	0.0	0.0	0.0	0.0	18.4	0.0	0.0	0.0
Schedule changes	1.8	0.0	0.0	0.0	14.1	11.5	23.7	0.0	−1.3
Inter- or intraprogram transfers	−12.7	0.0	0.0	0.0	48.7	5.9	−1.6	0.0	0.0
Financial	2.9	−2.4	−1.9	−0.8	6.4	1.4	−0.2	1.3	0.3
Exchange rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inflation	2.9	−2.4	−1.9	−0.8	6.4	1.4	−0.2	1.3	0.3
Miscellaneous	0.0	0.0	−0.4	0.0	0.0	0.0	0.0	0.0	0.0
Error correction	0.0	0.0	−0.4	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
External events	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table A.3 (continued)

Category	Patriot PAC3	AWACS RSIP	SMART-T	Stryker	T45TS	Titan IV	Trident II Missile	WGS
SAR date of final estimate	Dec 05	Dec 03	Dec 99	Dec 05	Dec 05	Dec 01	Dec 05	Dec 05
Percentage complete (by value)	96.4	100.0	84.7	87.7	100.0	99.4	99.1	63.8
Service	Army	AF	Army	Army	Navy	AF	Navy	AF
Type of system	Missile	Electronic	Electronic	Vehicle	Aircraft/ Helo	LS	Missile	SAT
Baseline development cost estimate ($ millions)	1,223.4	484.9	197.2	530.3	798.3	910.8	15,421.3	187.7
Development cost growth ($ millions)	1,680.8	35.6	170.3	198.9	396.2	4,067.9	−1,026.9	129.9
Errors	65.2	13.0	47.8	34.7	38.4	27.0	−7.3	−9.2
Cost estimate	65.2	13.6	47.8	24.3	38.4	24.9	−7.3	−9.2
Schedule estimate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technical issues	0.0	−0.6	0.0	10.4	0.0	2.0	0.0	0.0
Decisions	72.4	−6.9	40.7	2.1	12.3	210.3	0.4	78.5
Requirements	38.5	1.1	21.4	−4.7	0.9	92.4	0.9	34.0
Affordability	−2.6	−1.2	0.0	0.0	0.0	−12.0	0.0	−10.3
Quantity	0.0	0.0	0.0	6.8	0.0	9.9	−0.4	57.2
Schedule changes	25.8	9.8	0.0	0.0	0.0	45.1	0.0	0.0
Inter- or intraprogram transfers	10.7	−16.6	19.4	0.0	11.5	75.0	0.0	−2.3
Financial	−2.5	1.3	16.8	0.8	2.0	0.9	0.2	−0.1
Exchange rate	0.0	0.0	0.0	0.0	3.1	0.0	0.0	0.0
Inflation	−2.5	1.3	16.8	0.8	−1.1	0.9	0.2	−0.1
Miscellaneous	2.3	0.0	−19.0	0.0	0.0	208.5	0.0	0.0
Error correction	0.0	0.0	−19.0	0.0	0.0	0.0	0.0	0.0
Unidentified	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
External events	0.0	0.0	0.0	0.0	0.0	208.5	0.0	0.0

Table A.4
Percentage Growth in Procurement Cost for 35 Mature Weapons

Category	AFATDS	AMRAAM	ATACMS	B-IB	B-IB CMUP Computer	B-IB CMUP JDAM	BFVSA3	C-17	CBU-97B
SAR date of final estimate	Dec 98	Dec 05	Dec 99	Dec 92	Dec 04	Dec 99	Dec 05	Dec 05	Dec 98
Percentage complete (by value)	39.6	77.7	93.3	98.0	97.9	70.8	49.2	87.6	52.3
Service	Army	AF	Army	AF	AF	AF	Army	AF	AF
Type of system	Electronic	Missile	Missile	Aircraft/ Helo	Electronic	Electronic	Vehicle	Aircraft/ Helo	Munition
Baseline procurement cost estimate ($ millions)	771.7	11,275.2	720.8	37,645.7	179.0	231.8	3,208.7	34,969.4	2,612.5
Procurement cost growth ($ millions)	−26.3	888.3	1,101.6	−721.0	−71.1	3.2	4,558.6	17,729.6	−996.3
Errors	−31.6	20.8	−7.3	2.0	−23.0	−0.4	32.0	17.9	−3.3
Cost estimate	−33.4	17.4	−7.3	2.0	−17.5	−0.4	31.6	18.4	−12.1
Schedule estimate	1.7	0.0	0.0	0.0	−2.2	0.0	0.0	−0.5	8.8
Technical issues	0.0	3.4	0.0	0.0	−3.3	0.0	0.4	0.0	0.0
Decisions	27.9	−13.2	164.8	−5.7	−16.8	4.3	109.7	32.0	−35.8
Requirements	−3.5	4.7	25.3	0.9	0.0	0.0	14.1	5.2	3.3
Affordability	0.0	1.2	14.3	−5.9	0.0	0.0	0.0	−2.5	0.0
Quantity	31.4	−37.9	121.3	0.0	−16.8	−0.5	82.8	16.9	−44.2
Schedule changes	0.0	19.3	2.7	0.0	0.0	4.8	9.6	21.4	5.7
Inter- or intraprogram transfers	0.0	−0.4	1.2	−0.7	0.0	0.0	3.2	−9.0	−0.7
Financial	0.4	0.3	6.3	1.8	0.1	−2.5	1.0	0.8	1.0
Exchange rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inflation	0.4	0.3	6.3	1.8	0.1	−2.5	1.0	0.8	1.0
Miscellaneous	0.0	0.0	−11.0	0.0	0.0	0.0	−0.6	0.0	0.0
Error correction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified	0.0	0.0	−11.0	0.0	0.0	0.0	−0.6	0.0	0.0
External events	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table A.4 (continued)

Category	E-6A	F/A-18E/F	F-22	GBS	JAVELIN	JDAM	JPATS	JSOW	JSTARS
SAR date of final estimate	Dec 1	Dec 05	Dec 05	Dec 05	Dec 05	Dec 05	Dec 05	Dec 05	Dec 03
Percentage complete (by value)	99.8	70.7	60.6	61.6	92.7	76.3	41.5	87.4	96.3
Service	Navy	Navy	AF	AF	Army	AF	AF	Navy	AF
Type of system	Aircraft/ Helo	Aircraft/ Helo	Aircraft/ Helo	Electronic	Missile	Electronic	Aircraft/ Helo	Electronic	Aircraft/ Helo
Baseline procurement cost estimate ($ millions)	2,471.0	65,429.1	58,008.0	60.3	3,799.1	2,415.2	2,913.3	7,288.9	1,817.3
Procurement cost growth ($ millions)	−105.0	−26,525.3	−25,123.2	237.2	55.7	2,062.5	1,907.0	−3,414.0	4,287.3
Errors	5.1	−0.5	0.7	51.6	47.2	6.9	25.8	−45.2	107.4
Cost estimate	5.1	−0.5	0.7	51.6	46.6	1.0	25.8	−47.9	50.0
Schedule estimate	0.0	0.0	0.0	0.0	0.6	5.8	0.0	0.0	0.0
Technical issues	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	57.3
Decisions	−10.0	−41.7	−44.2	342.3	−46.7	79.2	40.1	−1.7	117.6
Requirements	−7.7	0.5	0.8	−57.5	4.0	−2.4	7.3	4.7	22.3
Affordability	−5.0	0.0	−0.2	−0.7	−0.1	0.0	0.4	−1.2	−3.5
Quantity	3.2	−36.8	−63.6	400.6	−48.3	79.1	12.8	−5.1	39.3
Schedule changes	−0.4	0.2	23.2	0.0	−2.7	3.8	19.6	0.0	58.8
Inter- or intraprogram transfers	0.0	−5.6	−4.4	0.0	0.4	−1.3	0.0	0.0	0.8
Financial	0.6	1.6	0.1	−0.4	1.0	−0.7	−0.4	0.0	10.9
Exchange rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inflation	0.6	1.6	0.1	−0.4	1.0	−0.7	−0.4	0.0	10.9
Miscellaneous	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Error correction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
External events	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table A.4 (continued)

Category	JSTARS CGS	Longbow Apache AF	Longbow Apache FCR	Longbow Hellfire	MCS	MIDS LVT	MM GRP	MM PRP	OH-58D
SAR date of final estimate	Dec 01	Dec 05	Dec 03	Dec 04	Dec 04	Dec 05	Dec 05	Dec 05	Jun 95
Percentage complete (by value)	93.1	74.3	97.9	99.2	74.4	70.7	81.4	65.6	97.4
Service	Army	Army	Army	Army	Army	Navy	AF	AF	Army
Type of system	Electronic	Aircraft/ Helo	Electronic	Missile	Electronic	Electronic	Electronic	LS	Aircraft/ Helo
Baseline procurement cost estimate ($ millions)	734.6	1,290.9	652.9	1,718.9	343.2	509.7	1,259.5	2,268.8	2,781.3
Procurement cost growth ($ millions)	59.9	6,790.9	253.8	466.2	−110.8	472.4	681.2	−59.1	967.8
Errors	−7.3	145.2	36.9	−48.4	−51.3	−48.0	22.1	−3.7	23.0
Cost estimate	−44.7	88.3	25.9	−35.3	−51.2	−48.0	20.6	−3.3	23.0
Schedule estimate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	−0.3	0.0
Technical issues	37.5	57.0	11.0	−13.1	0.0	0.0	1.5	0.0	0.0
Decisions	11.8	381.9	0.3	73.7	16.2	139.6	31.4	−2.1	10.0
Requirements	54.9	126.5	10.0	1.4	−1.9	−53.7	−4.3	0.0	35.4
Affordability	−19.9	11.4	−1.8	0.0	0.0	0.0	7.0	−0.7	−1.8
Quantity	19.3	205.8	−20.9	17.8	24.1	165.4	0.7	−0.6	−30.7
Schedule changes	4.0	−0.5	12.9	54.5	0.0	32.2	27.0	−0.8	7.0
Inter- or intraprogram transfers	−46.5	38.8	0.0	0.0	−5.9	−4.3	0.9	0.0	0.0
Financial	5.4	1.0	2.2	1.8	2.8	1.1	0.6	0.8	1.8
Exchange rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Inflation	5.4	1.0	2.2	1.8	2.8	1.1	0.6	0.8	1.8
Miscellaneous	−1.8	−2.1	−0.5	0.0	0.0	0.0	0.0	2.4	0.0
Error correction	−1.8	−2.1	−0.5	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
External events	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	0.0

Table A.4 (continued)

Category	Patriot PAC3	AWACS RSIP	SMART-T	Stryker	T45TS	Titan IV	Trident II Missile	WGS
SAR date of final estimate	Dec 05	Dec 03	Dec 99	Dec 05	Dec 05	Dec 01	Dec 05	Dec 05
Percentage complete (by value)	75.9	95.3	44.1	55.0	90.5	100.0	70.0	42.7
Service	Army	AF	Army	Army	Navy	AF	Navy	AF
Type of system	Missile	Electronic	Electronic	Vehicle	Aircraft/Helo	LS	Missile	SAT
Baseline procurement cost estimate ($ millions)	2,583.0	308.0	754.4	6,200.9	4,621.9	2,467.9	27,659.2	858.9
Procurement cost growth ($ millions)	3,948.1	311.2	−106.9	2,470.4	1,701.7	13,743.4	2,438.7	745.2
Errors	67.2	75.3	8.5	4.9	43.1	26.5	−5.2	20.2
Cost estimate	67.2	59.5	8.5	1.3	42.0	12.6	−5.2	2.2
Schedule estimate	0.0	15.8	0.0	0.0	1.1	0.0	0.0	0.0
Technical issues	0.0	0.0	0.0	3.6	0.0	13.9	0.0	17.9
Decisions	84.9	20.7	−20.1	35.1	−6.7	451.2	14.6	65.9
Requirements	19.8	27.1	6.4	0.6	1.8	61.1	23.5	2.7
Affordability	4.4	0.0	−0.4	0.0	0.0	−6.7	−1.0	−3.2
Quantity	50.6	−8.6	−20.6	20.8	−11.8	413.4	−11.2	81.9
Schedule changes	15.3	8.0	0.5	13.7	3.3	0.0	4.0	1.4
Inter- or intraprogram transfers	−5.1	−5.8	−6.0	0.0	0.0	−16.6	−0.7	−17.0
Financial	0.8	5.0	4.4	−0.3	5.2	8.2	−0.6	0.7
Exchange rate	0.0	0.0	0.0	0.0	4.7	0.0	0.0	0.0
Inflation	0.8	5.0	4.4	−0.3	0.5	8.2	−0.6	0.7
Miscellaneous	0.0	0.0	−7.0	0.1	0.0	71.1	0.0	0.0
Error correction	0.0	0.0	−7.0	0.0	0.0	0.0	0.0	0.0
Unidentified	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
External events	0.0	0.0	0.0	0.0	0.0	71.1	0.0	0.0

Weighted Cost Growth

In Chapter Three, we presented our cost-growth findings as simple averages for the 35 mature programs. However, if we want to look at the total budget impact rather than the effects on individual programs, we need to examine weighted averages (in dollars). Table B.1 shows the overall cost growth after all program costs have been converted from their original base year to FY 2005 dollars and summed. The Air Force Raw Inflation Indices dated January 19, 2006, for base year 2005 were used in the conversions. This table includes development, procurement, and total costs from MS B through the last program SAR or the December 2005 SAR (for programs that were active as of the end of 2005). The percentage cost growth by category and appropriation for all programs after conversion to FY 2005 dollars is shown in Table B.2.

These results differ from those discussed previously and shown in Tables 3.1 and 3.2. Conversion to common base-year dollar values and summation effectively weights the results by program size. Also, throughout this analysis, program cost data are not normalized for changes in the quantity produced. The quantity entry in the decisions category represents the cost growth resulting from those changes.

These data are of no use for analyzing unit cost growth, which would require that in each program the number of units accounted for in the MS B baseline and final estimate be made equal through an adjustment of either the baseline estimate or the final estimate. We did not make those adjustments in this study.

Table B.1
Distribution of Total Cost Growth for 35 Mature Programs
(millions of FY 2005 dollars)

Item	Development	Procurement	Total
Final cost	102,373.8	303,672.4	406,046.2
Baseline cost	73,400.6	292,831.0	366,231.6
Cost growth	28,973.2	10,841.4	39,814.6
Errors	9,637.6	16,960.6	26,598.2
Cost estimate	9,157.4	13,424.6	22,582.0
Schedule estimate	270.5	307.7	578.2
Technical issues	209.7	3,228.3	3,438.0
Decisions	16,923.0	−10,749.1	6,173.9
Requirements	7,234.9	16,511.2	23,746.1
Affordability	−1,344.2	−3,532.6	−4,876.9
Quantity	−1,060.3	−42,967.6	−44,027.9
Schedule	7,142.0	29,605.8	36,747.7
Program transfers	4,950.7	−10,365.8	−5,415.1
Financial	571.9	2,996.7	3,568.6
Exchange rate	24.5	218.5	243.0
Inflation	547.3	2,778.2	3,325.5
Miscellaneous	1,840.7	1,633.3	3,473.9
Error correction	−23.6	−96.2	−119.8
Unidentified	−34.9	−78.8	−113.7
External events	1,899.1	1,808.3	3,707.5

There are five relatively large programs in our sample: B-1B, C-17A, F/A-18E/F, F-22, and Trident II. The average total final cost of these programs was more than $50 billion in base year 2005 dollars. The development plus procurement costs of the five programs, adjusted to equal "purchasing power" through conversion to base year 2005 dollars, make up 64 percent of the aggregate for the entire 35-program sample. Three of the five programs—B-1B, C-17A, and F-22—belong to the Air Force, and four of the five are aircraft programs. These large programs dominate the weighted and summed results shown in Tables B.1 and B.2.

Table B.2
Percentage Cost Growth for 35 Mature Programs

Category	Development	Procurement	Total
Errors	13.1	5.8	7.3
Cost estimate	12.5	4.6	6.2
Schedule estimate	0.4	0.1	0.2
Technical issues	0.3	1.1	0.9
Decisions	23.1	−3.7	1.7
Requirements	9.9	5.6	6.5
Affordability	−1.8	−1.2	−1.3
Quantity	−1.4	−14.7	−12.0
Schedule changes	9.7	10.1	10.0
Program transfers	6.7	−3.5	−1.5
Financial	0.8	1.0	1.0
Exchange rate	0.0	0.1	0.1
Inflation	0.7	0.9	0.9
Miscellaneous	2.5	0.6	0.9
Error correction	0.0	0.0	0.0
Unidentified	0.0	0.0	0.0
External events	2.6	0.6	1.0
Total	39.5	3.7	10.9

NOTE: Sums of subcategories may not add exactly to the totals because of rounding.

Comparison of Tables 3.1 and 3.2 with Table B.2 shows that when one examines total rather than average cost growth, the percentages decrease, sometimes significantly. In development, for example, the combined overall growth rate is about 40 percent, while the average cost growth is 57 percent, implying that the cost growth is relatively smaller in the larger programs. Similarly, for procurement costs, although the mean growth rate is 75 percent, the combined total growth rate is only 4 percent. This occurs in large part because the F/A-18E/F and F-22 programs, two of the largest in the study, had large negative procurement cost growth because of substantial quantity reductions.

Tables B.3 and B.4 present the distribution of total cost growth and combined percentage cost growth for the Air Force programs in our study.

Table B.3
Distribution of Total Cost Growth for 16 Mature Air Force Programs
(millions of FY 2005 dollars)

Category	Development	Procurement	Total
Final cost	65,870.4	174,916.4	240,786.8
Baseline cost	41,233.3	159,290.9	200,524.1
Cost growth	24,637.1	15,625.5	40,262.7
Errors	8,514.3	13,803.2	22,317.5
Cost estimate	8,261.2	11,645.0	19,906.2
Schedule estimate	112.9	219.1	332.0
Technical issues	140.2	1,939.1	2,079.3
Decisions	13,819.2	–1,514.0	12,305.2
Requirements	5,115.1	5,306.9	10,422.0
Affordability	–1,246.3	–3,194.3	–4,440.6
Quantity	–1,383.9	–22,371.6	–23,755.5
Schedule	6,694.0	25,329.1	32,023.1
Program transfers	4,640.4	–6,584.2	–1,943.8
Financial	464.1	1,515.1	1,979.2
Exchange rate	0.0	0.0	0.0
Inflation	464.1	1,515.1	1,979.2
Miscellaneous	1,839.5	1,821.3	3,660.7
Error correction	0.0	0.0	0.0
Unidentified	–59.6	12.9	–46.7
External events	1,899.1	1,808.3	3,707.5

Comparison of Table 3.7 with Table B.4 for Air Force programs shows that cost growth decreases from 95 percent to about 10 percent in procurement and from 66 percent to 20 percent at the total level. These decreases are driven by large negative growth in the quantity procured, which came almost entirely from the decrease in the quantity of F-22 aircraft, and somewhat compensate for growth in other areas of Air Force costs. Development cost growth was essentially unchanged at about 60 percent.

Decisions to change schedule, which account for 16 percent of cost growth in the Air Force programs, are a huge contributor to the total cost growth of 20 percent. When measured as a simple average value, schedule-change decisions account for only 11 percent, one-sixth of the total shown in Table 3.7.

Table B.4
Percentage Cost Growth for 16 Mature Air Force Programs

Category	Development	Procurement	Total
Errors	20.6	8.7	11.1
Cost estimate	20.0	7.3	9.9
Schedule estimate	0.3	0.1	0.2
Technical issues	0.3	1.2	1.0
Decisions	33.5	−1.0	6.1
Requirements	12.4	3.3	5.2
Affordability	−3.0	−2.0	−2.2
Quantity	−3.4	−14.0	−11.8
Schedule changes	16.2	15.9	16.0
Program transfers	11.3	−4.1	−1.0
Financial	1.1	1.0	1.0
Exchange rate	0.0	0.0	0.0
Inflation	1.1	1.0	1.0
Miscellaneous	4.5	1.1	1.8
Error correction	0.0	0.0	0.0
Unidentified	−0.1	0.0	0.0
External events	4.6	1.1	1.8
Total	59.8	9.8	20.1

NOTE: Sums of subcategories may not add exactly to the totals because of rounding.

Trigger Events

It is also possible and meaningful to examine cost growth due to root sources within a program. These root causes might act as "trigger events" that set into motion a series of program changes that culminate in cost growth that is recognized all at once or over a period of time. A process for identifying such trigger events and their repercussions is shown schematically in Figure C.1.

An initial problem (or set of problems) builds up until it culminates in a trigger event, which could be as simple as the formal recognition of the problem and the decision to deal with it. This decision might result in any number of future actions, including a change in technology and corresponding redesign costs, higher unit prices, a reduction in procurement quantity, schedule modification, and possibly reprogramming of project funding by Congress or the Air Force.

A serious technical problem that could not be resolved without a major redesign effort, for example, might be a trigger event. Such a problem could lead to not only delays in system development, but subsequent postponement of integration and testing, additional development costs, higher unit costs for procurement, and difficulty meeting volume or weight constraints. Accordingly, it might be necessary to redesign other components of the system to compensate and meet system requirements.

Using the SAR cost-variance categories, other narrative program information in the SARs, and the cost-variance values, we identified such causes and critical events in the history of each program and estimated the cost growth associated with them.

Figure C.1
Schematic Diagram of Event-Driven Cost Growth
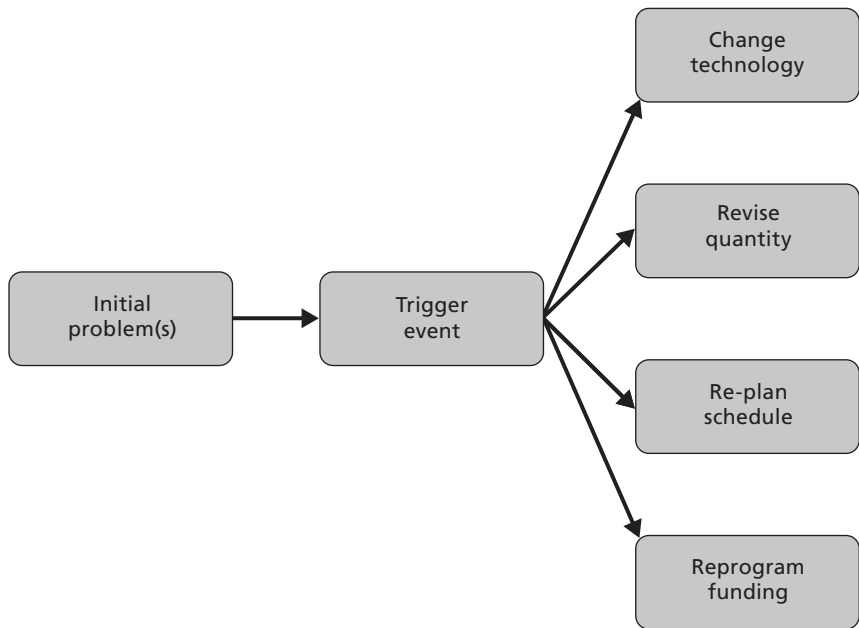
Table C.1 summarizes what we consider the most important trigger events from the 35 mature programs in our study. The table illustrates several important points. First, not all programs have trigger events; we found one or more such events in only 23 of the 35 programs in our sample. This is not to say that there were no situations in the remaining programs that could be called trigger events, however. It would be more accurate to say that these programs did not have significant issues that could be identified from the information in the SARs.

There is no consistent pattern of trigger events across programs. Some of the trigger events we identified occurred only in development, some occurred only in procurement, and others occurred in both. In some programs, including the AFATDS program, the trigger event (persistent software development problems) affected both development and procurement. In others, such as the AMRAAM program, the decision to extend the program and change the production rate triggered

Table C.1
Trigger Events for 35 Mature Programs (millions of base year 2005 dollars)

Program	Event	Development			Procurement		
		Baseline	Growth	Percent	Baseline	Growth	Percent
AFATDS	Software development	520.9	157.7	30.3	771.7	70.1	9.1
AMRAAM	P3I program	1,871.2	940.7	50.3			
	Complexity & ICA				11,275.2	2,294.1	20.3
	Schedule & duration				11,275.2	3,775.0	33.5
	Learning curve error				11,275.2	2,146.8	19.0
ATACMS	P3I program	969.5	111.4	11.5			
AWACS RSIP	Hardware/software development	484.9	110.0	22.7	308.0	47.4	15.4
	Misestimation of costs				308.0	129.6	42.1
	Schedule slip from funding				308.0	44.5	14.5
B-1B	Flight test problems	4,904.1	747.7	15.2			
BFVSA3	Cancellation of Armored Gun System				3,208.7	100.9	3.1
	Stretch procurement program				3,208.7	384.4	12.0
C-17	Misestimation of costs	5,562.6	2,543.8	45.7	34,969.4	9,093.9	26.0
	Continuing product improvement	5,562.6	1,019.0	18.3			
	Redefinition of spares/support				34,969.4	1,467.2	4.2
	Restructure buy program				34,969.4	6,352.1	18.2
CBU-97B	Misestimation of costs	193.7	33.8	17.5	2,612.5	91.3	3.5
	P3I program	193.7	74.0	38.2	2,612.5	105.8	4.0
	Restructure buy program				2,612.5	405.9	15.5
F-22	Restructure program funding	22,078.0	3,330.9	15.1	58,008.0	13,567.8	23.4
	Flight test extension	22,078.0	565.5	2.6			
	System modernization	22,078.0	2,803.2	12.7			
F/A-18 E/F	Change mix of E and F models				65,429.1	362.9	0.6
Javelin	Delay and rephase program	732.2	145.7	19.9	3,799.1	23.1	0.6

Table C.1 (continued)

Program	Event	Development			Procurement		
		Baseline	Growth	Percent	Baseline	Growth	Percent
JDAM	Requirements growth	566.4	157.0	27.7			
	Restructure buy profile				2,415.2	236.2	9.8
JPATS	Misestimation of vendor costs				2,913.3	498.9	17.1
	Bad unit costs & program stretch				2,913.3	547.8	18.8
	Altered support requirements				2,913.3	418.4	14.4
JSTARS	Switch to new build aircraft				1,817.3	1,846.8	101.6
	System modernization	2,003.8	1,396.9	69.7	1,817.3	1,142.2	62.8
	Rephasing and reestimation	2,003.8	1,495.9	74.7	1,817.3	1,739.2	95.7
	Switch to used aircraft; FSD#3 config upgrade	2,003.8	421.9	21.1	1,817.3	−879.3	−48.4
Longbow Hellfire	Develop counter active protection	387.8	47.4	12.2			
MCS	Software development	146.8	196.9	134.2			
MM III GRP	Evolving requirements	512.5	−71.7	−14.0	1,259.5	79.4	6.3
	Restructure program funding	512.5	121.4	23.7	1,259.5	340.6	27.0
	Misestimation of costs	512.5	24.7	4.8	1,259.5	293.6	23.3
	Diminishing supplier effects				1,259.5	54.5	4.3
OH-58D	Stretch and restructure program				2,781.3	139.6	5.0
Patriot PAC3	Program extension & development problems	1,223.4	910.2	74.4	2,583.0	1,000.7	38.7
T45TS	Test deficiency stretch				4,621.9	392.0	8.5
	Program restructure				4,621.9	113.9	2.5
Titan IV	Challenger accident	910.8	2,090.2	229.5	2,467.9	2,142.5	86.8
	Decision to develop SRMU	910.8	670.4	73.6	2,467.9	1,222.3	49.5
	P3I and range safety design	910.8	181.9	20.0			
Trident II	Defer procurement and stretch program				27,659.2	1,251.6	4.5
	Extend production				27,659.2	873.4	3.2
WGS	Addition of satellites	187.7	171.0	91.1	858.9	728.5	84.8
	Separation of other programs				858.9	−134.1	−15.6

significant increases in procurement costs but did not affect development. A few programs, including the Longbow Hellfire missile and the B-1B, had development issues but no clear triggering events during procurement. Others, such as the Bradley upgrade (BFVSA3) and the JPATS had specific problems during procurement but none in development. In general, there seem to be no clear patterns in the nature, magnitude, or timing of trigger events in programs.

Table C.1 also shows that trigger events play vastly different roles in different programs. The growth percentages shown are the amounts of cost growth potentially associated with the events, not the fraction of total cost growth. Thus, the Challenger accident and subsequent program modifications were associated with development cost growth of 230 percent and procurement cost growth of 87 percent in the Titan IV program. This is significantly less than the total cost growth experienced by the program, 447 percent during development and 557 percent in procurement. Moreover, trigger events do not always increase cost growth, as illustrated by the MM III GRP program, where evolving requirements during development reduced costs by 14 percent, offsetting some of the cost growth caused by restructuring program funding.

These events generally echo the results discussed earlier. Program restructuring, changes in schedules, increased requirements (either alone or as continuing product-improvement programs), and errors in initial cost estimates are common significant triggering events. The most common technical issue in the programs we examined was software development, which can be responsible for significant growth in development costs. Table C.1 shows such growth explicitly in several programs, but it also underlies cost growth in other programs where it was not explicitly identified in the cost-variance information of the SARs.

As we have seen, the concept of trigger events has limited value in identifying the reasons for cost growth in programs. We can identify such events in some cases and associate cost growth with them, but this should not be considered conclusive. Trigger events do not by themselves solve the problem of identifying why cost growth occurs. It is not always possible to identify a root cause or to associate cost

growth with a triggering source. Not all programs have such events, and cost growth in many cases may simply be the result of continuing technical and managerial issues or other factors that cannot be associated with a specific, identifiable cause. Finally, even when a triggering event or issue can be identified, it may not be possible to generalize the issue and use it to predict or control cost growth in other programs in the future.

OSD Guidance and Definitions of the SAR Cost-Variance Categories

SARs have included a cost-variance section since their inception in the late 1960s. The category names have remained consistent, but the instructions on how to allocate cost changes to the categories have changed over the years. Training in the preparation and review of the SAR is currently provided by the Defense Acquisition University (DAU) through its Acquisition Reporting Course (BCF 209/229). However, we have no way of knowing

1. How consistently SAR preparers were trained over the past four decades
2. How consistently SARs were reviewed
3. How often SARs were rejected due to failure to fully follow preparation guidelines.

This appendix presents the SAR cost-variance preparation direction as of May 2006. The following text is reproduced directly from the SAR Preparation Instructions found in paragraph 13 of the *Consolidated Acquisition Reporting System (CARS) Users Guide*.

Cost Variance Analysis. Quantify and briefly summarize the significant cost variances between the SAR baseline (specify Planning Estimate (PE), Development Estimate (DE), or Production Estimate (PdE), whichever is applicable) and the Current Estimate.

a.   **Summary.** The cost variances will be identified and reported according to the change categories defined in paragraphs 13.a(1) and 13.a(2), below, and tabulated as previous changes or current changes. Previous changes are the cumulative total of all changes identified from current SAR baseline through the previous SAR (annual or quarterly), and current changes are those occurring since the previous SAR. The SAR baseline and Current Estimate as well as the previous and current changes will be shown in then-year dollars (first table) and in base-year dollars (second table) for RDT&E, procurement, military construction, and acquisition-related operation and maintenance.

(1) **Changes.** All changes to the cost variance categories (defined in paragraph 13.a(2), below), whether in the previous changes section or in the current changes section, are defined as either "economic" or "program" changes.

(a) **Economic Changes.** As defined in paragraph 13.a(2), below, these include changes in the Current Estimate resulting from actual escalation different from that previously assumed and from revisions to prior assumptions of future escalation. Since this category includes only those changes due to revisions in the assumptions of historical and future escalation, it applies only to the then-year dollar variance analysis. The Office of the Secretary of Defense escalation rates published with the President's Budget will be reflected in the annual SAR; these same rates will be reflected in subsequent 2nd, 3rd, or 4th quarterly SAR submissions. Prior approval of the USD(AT&L) is required for economic changes based on system-specific rates in prior years.

(b) **Program Changes.** These include all types of cost changes listed in paragraph 13.a(2), below, other than economic changes. Such program changes will provide the best estimate of costs including experienced and projected escalation. Enter the cost for the program changes in then-year dollars (first table) and in base-year dollars (second table) by appropriation for each cost variance category. When nega-

tive program changes affect the current provision for economic escalation, report their associated escalation as an economic change, to the extent such escalation previously was reflected in the Current Estimate; adjust the other categories as appropriate.

(2) **Cost Variance Categories.** Identify cost estimate variances separately for RDT&E, procurement, military construction, and acquisition-related operation and maintenance. Classify each according to the following categories: economic, quantity, schedule, engineering, estimating, other, and support. When multi-category changes occur, variances will be calculated in the above order to ensure the appropriate cost allocations are made. (NOTE: The quantity, schedule, engineering, estimating, and other categories are associated with changes in the work breakdown structure (WBS) elements identified as flyaway, rollaway, or sailaway costs in DoD 5000.4-M, "Cost Analysis Guidance and Procedures.") Quantity-related changes should also be explicitly identified. An example of a quantity-related change would be a reduction in initial spares requirement due to a quantity reduction. (The CARS software will allow the identification of cost changes that are associated quantity changes; and it will then automatically print "(QR)" at the end of a quantity related change explanation.)

(a) **Economic Change.** A change due only to price level changes in the economy. This includes changes in the Current Estimate resulting from actual escalation different from that previously assumed and from revisions to prior assumptions of future escalation. As previously noted, economic changes apply only to the then-year dollar variance analysis and the same rates are to be applied throughout the fiscal year. (Economic changes are not acquisition reform savings or quantity-related changes.)

(b) **Quantity Change.** A change in the number of development or production units of an end item of equipment. Ordinarily, categorization as a quantity change will be limited

to those end items for which unit costs are required and for which cost-quantity has been submitted. All quantity changes will be calculated using the baseline cost-quantity relationship in effect (Planning Estimate (PE), Development Estimate (DE), or Production Estimate (PdE), whichever is applicable). (Note that the baseline cost-quantity relationship is expressed in base-year dollars.) The difference between the cost of the quantity change based on the baseline cost-quantity relationship and the cost based on the Current Estimate cost-quantity relationship will be allocated to schedule, engineering, and estimating categories, as appropriate (for example, "allocation to estimating category due to quantity decrease"). Quantity changes in support items are categorized as "support," and are not included here. Also, quantity changes are not applicable to the military construction and operations and maintenance appropriations. (Quantity changes may be acquisition reform savings changes.)

(c) **Schedule Change.** A rephasing of development effort or a change in a procurement or delivery schedule milestone. Changes in support items are not included. (Schedule changes may be acquisition reform savings and quantity-related changes.)

(d) **Engineering Change.** An alteration in the physical or functional characteristics of a system or item delivered, to be delivered, or under development, after establishment of such characteristics. Changes in support items are not included. (Engineering changes may be acquisition reform savings and quantity-related changes.)

(e) **Estimating Change.** A change in program cost due to refinement of a prior Current Estimate, a change in program or cost estimating assumptions and techniques not provided for in the quantity, engineering, or schedule variance categories (for example, the adjustment for assumptions on current and prior escalation rates), or correction of an error

in preparing the baseline cost estimate. Changes in support items are not included. (Estimating changes may be acquisition reform savings and quantity-related changes.)

(f) **Other.** Use of this category must be preapproved by the OUSD(AT&L) and is appropriate only for the most unusual circumstances such as a change in program cost due to natural disasters, work stoppage, and similarly unforeseeable events not covered in other variance categories. The only other use for this category is to record the RDT&E and military construction reductions to terminated programs that have not yet entered production. (Other changes are not acquisition reform savings or quantity-related changes.)

(g) **Support Change.** Any change in cost, regardless of reason, associated with any work breakdown structure element not included in the flyaway, rollaway, or sailaway costs as defined in DoD 5000.4-M, "Cost Analysis Guidance and Procedures." This category generally includes all costs changes associated with training and training equipment, peculiar support equipment, data, operational site activation, and initial spares and repair parts. However, construction costs funded by the military construction appropriation associated only with operational site activation will be categorized elsewhere (except quantity). Note that the total support change (previous plus current) will equal the difference between the support items in the SAR baseline and the support items in the Current Estimate as shown in SAR paragraph 11.a. (Support changes may be acquisition reform savings and quantity-related changes.)

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